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ENERGY FACILITIES STORM HAZARD ANALYSIS

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FLORIDA DEPARTMENT OF COMMUNITY AFFAIRS

OF RESOURCE PLANNING AND MANAGEMENT

ZONE PROGRAMS

, Jr., AIA, Architect, Secretary

ENERGY FACILITIES STORM HAZARD ANALYIS

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This document was promulgated at an annual cost of ______or_____ per copy for the purpose of providing information on storm hazards associated with energy facilities in the coastal zone.

This report was prepared by James E. Truesdell of the Coastal Zone Program Section with clerical support provided by Deborah Walden and Sandra Saunders.

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ABBREVIATIONS

CCCL - Coastal Construction Control Line

DCA - Department of Community Affairs

DNR - Department of Natural Resources

FCG - Florida Electric Coordinating Group

NFIP - National Flood Insurance Program

PPSA - Power Plant Siting Act

PSC - Public Service Commission

TYSP - Ten Year Site Plan

I. Introduction

A. Purpose

The purpose of this project is to determine the potential number of energy facilities in the coastal high hazard areas which would be subject to damage from hurricanes and other coastal hazards and to propose design modifications to building codes which would serve to mitigate or reduce the damage potential for such facilities.

The "Coastal Zone Protection Act of 1985" (Chapter 161.52-161.56, Florida Statutes) requires all local governments with jurisdictions fronting on the Gulf of Mexico, Atlantic Ocean, Straights of Florida, or Florida Bay to establish a coastal building zone. Within this zone increased construction standards for major habitable structures will apply.

Florida's innovative growth management legislation seeks to minimize damage from intense development pressure through imposition of strict construction standards and other land and water use regulations. The building codes and construction control lines for coastal high hazard areas, while applicable to habitable structures, have important significance to other building and redevelopment activity, particularly in the aftermath of destructive storm events such as hurricanes and floods. Power plants and other energy facilities which have been damaged in a storm event or other catastropic event must consider the option of rebuilding in the same location at higher design standards or relocation of the facility away from the hazards associated with the coast. These decisions are a part of overall coastal zone management and must be viewed in the context of land use regulations by local and state governments.

The growth management legislation has important significance to coastal zone management activities in that local government comprehensive plans for development and redevelopment activity must address hazards associated with coastal flooding due to hurricanes,in hazard mitigation planning documents. Building in coastal high hazard areas is strictly regulated by the state, and local units of government are required to monitor closely those activities which may have adverse impacts upon land use.

As required in the Coastal Zone Protection Act all major structures including residential, commercial, institutional, and industrial mut be constructed to meet new minimum building requirements. Electrical power plants are specifically exempted from the new building requirements, however, all other energy facilities must comply.

Two major water-related coastal activities involved with energy are electrical generating facilities and Outer Continental Shelf oil and gas operations. Many OCS activities such as service bases and pipelines, must have shoreline locations. Florida electrical power companies often must look to the coast for cooling water because of constraints on freshwater consumption. Careful siting and design of these facilities is a necessary part of efforts to meet energy needs.

As energy will continue to be a major issue in the future, the development of OCS-related oil and natural gas activities must be balanced with the protection of the natural and human environments. Major oil and gas operations will create environmental problems in the coastal areas. In addition, they will be subject to damage from hurricane related storm events which may in turn, create disaster problems from unmitigated damage.

II. Location of Energy Facilities in the Coastal Zone

A. Power Plant Siting

From its beginning in the 1800's, the electrical power industy's methodologies and rationale of central generating station planning and operation have closely paralled the advance of our developing social organization. At the beginning of the technological expansion, the primary objective of siting a plant was to find a location that provided power at the lowest possible cost. In order to reduce the complexity and design of the transmission system and to appear physically more visible and dependable to their largest customers, generating facilities wee located in, or near, the industrial sections of towns and cities. This siting usually resulted in access to industrial water supplies and easier fuel transportation. The opportunities afforded by this procimity to the utility's load center, combined with the small generating stations of municipal vintage, provided the main rationale in the early sitings (Winter, 1978).

The growth of our communities preempted land acquisition for future utility expansion as the loads increased. Zoning code restrictions often excluded power plants from prime industrial sites. The continued need for a dependable power supply forced the utilities to move to the suburbs and beyond, to coastal areas. Consequently, transmisison line investments and the subsequent improvement of distribution systems resulted in higher capital investments.

As the expansion of cities continued and the demand for land and water resources became more competitive, utilities were forced farther and farther from the load centers. Economic trade-offs were required to offset the greatly increased transmission and delivery costs. Higher transmission voltages were utilized. Increased equipment efficiencies and "economies of scale" were used to generate larger quantities of power at decreased incremental costs. Fuel and transportation costs were minimized by locating energy facilities near, or easily accessible to, fuel sources and water supplys. The siting methodology evolved to defining the most economical area in which to construct a facility and acquisitioning of as much land as possible at the lowest cost possible (Morrel et al., 1978). Although many site selection variables are examined in the siting process, the necessity for an adequate supply of water is critical to site selection. Location of energy facilities in coastal regions has the two fold advantage of abundant water supply for the energy facility and the use of water for various transportation, disposal operation, and purification processes.

Rivers, lakes, reservoirs, and groundwater are all potential water sources for energy facilities. Each source possess particular advantages and disadvantages. For example, the use of groundwater, while offering easy access in particularly any situation, is limited by the withdrawal rate and the amount available in subsurface aquifiers. Although a viable alternative for medium-sized plants, groundwater supplies cannot approach the needs of large generating complexes.

When considering sites along lakes, rivers and estuaries, detailed records are required to determine the extent of water resources. Adequate water supply must be assured during period of low flow. Aggregate use of water from upstream and downstream consumption must also be predicted, especially when there is common use by industries and communities for irrigation, transportation, and sewage disposal. While these waterways are considered to be renewable resources with the ability to assimulate and purify discharges, this very capability breaks down in the face of excessive chemical and solid waste discharge.

Therefore, purification of inlet and discharged water is often necessary in the design of a system (Nelson, 1976). Finally, thermal discharges to the lakes, rivers and estuaries, although limited by cooling water system design, is a constraint upon the utilization of these water bodies. Care must be taken to predict and measure the water temperature and its variations at specific site locations in order to properly design an efficient and acceptable system.

Siting in coastal zones negates many of the common use problems associated with lakes and rivers. However, location in coastal zones presents problems associated with the potential devasting effects of hurricanes, floods, and other catastrophic events. Tidal effects and wave action during a storm event can cause damage to energy facilities which may negate the economic attraction of a coastal location (Morrel et. al. 1980).

B. The Florida Power Plant Siting Act

Passed in the 1983 legislative session, the Florida Electrical Power Plant Siting Act (PPSA) became effective July 1, 1973. The PPSA was designed to provide a one-stop site certification procedure for construction or expansion of steam, solar or nuclear electrical power plants. It also provided for coordination of long-range planning by electric utilities with local and state planning agencies.

The legislative intent of the PPSA was to provide a centrally coordinated state approval system for each proposed site. The act recognized that selection of power plant sites and associated transmission corridors would have a significant impact on the welfare of the population, location and growth of industry, and the use of the state's natural resources. Under the act, a new plant would be issued a permit only after a review conducted by a number of state agencies.

In the PPSA, the Legislature recognized the need for power generation facilities. But it also stated, in section 403.502, that the legislative intent is to ensure that "the location and operation of electrical power plants will produce minimal adverse effects on human health, the ecology of the land and its wildlife, and the ecology of state waters and their aquatic life." The legislative intent is for the governor and cabinet, acting as the siting board to balance the increasing demands for electrical energy with the broad interests of the public.

Since the enactment of the PPSA, it has been amended a number of times. In 1975 final certification authority was given to the Florida Cabinet, and the Division of Administrative Hearing was assigned the authority to conduct the certification hearing. In 1976 Water Management Districts were added to the review process by administrative rule, and in 1981 they became a party by statute. In 1980, the Legislature adopted language making the Florida Public Service Commission (PSC) the exclusive agency of state government authorized to certify the need for a new power plants and transmission lines. The amendment directed the PSC to consider both the cost-effectiveness of a proposed facility, and the role of conservation in meeting future need for power.

In 1979 power plants less than 50 megawatts (MW) in size were exempted from the act, but in 1981 the PPSA was amended to allow applicants for units smaller than 50 MW to use the PPSA voluntarily. In 1986 powers plants less than 75 MW in size were exempted from the act.

The Power Plant Siting Act establishes a nine-step process for the certification of a proposed power plant. These steps are as follows:

1. Pre-application discussions
2. The Need for Power Order of the Public Service Commission
3. DER review for sufficiency and completeness
4. Certification review and studies
5. Land use hearing
6. The certification hearing
7. The Recommended Order of the Division of Administrative Hearings
8. The Order of the Governor and Cabinet
9. Post-certification review by DER

This process is used for both new power plant site applications and for "supplemental" applications--i.e., those applying for an addition to an existing site.

Although power plant siting in Florida is governed by the Power Plant Siting Act, there are other statutes that also apply to the certification procedure.

C. Coastal Zone Conflicts

Florida's Coastal zone, like other natural resources, have been stressed heavily by the state's burgeoning growth. The delicate coastal areas and fragile barrier islands are threatened by Florida's population explosion and the competing need for new and renewable energy eources. Developers are eager to build new housing subdivisions to accomodate the nearly 800 new people moving to the state each day. And they know that many of the new residents will want to live near the Gulf or Atlantic coast. About 80 percent of the state's population reside in its 35 coastal counties (see Table 1). The development of coastal area has accelerated so rapidly in recent years that 90% of all coastal dwellings have not weathered a major storm or hurricane. Until hurricanes Kate and Elena in 1985, the state had not been hit directly by a major storm since the early 1960s. This booming coastal growth has increased the risk to both residents and structures in the coastal high hazard areas. Because

Table 1
Population of Coastal Counties

	1980	1985	1990	1995	2000
Bay	97,740	113,714	127,146	138,067	149,924
Brevard	272,959	327,659	374,699	413,691	454,762
Broward	1,018,200	1,153,760	1,300,090	1,417,941	1,591,683
Charlotte	58,460	77,852	97,475	114,257	132,077
Citrus	54,703	74,043	94,719	109,316	126,233
Collier	85,971	114,069	192,305	164,538	188,511
Dade	1,625,781	1,799,411	1,894,490	1,971,212	2,045,437
Dixie	7,751	9,566	11,176	12,555	13,970
Duval	571,003	599,278	614,739	635,561	649,942
Escambia	233,794	258,987	276,799	289,555	303,811
Flagler	10,913	15,744	20,733	24,733	29,122
Franklin	7,661	8,080	8,287	8,542	8,727
Gulf	10,658	11,141	11,366	11,720	11,943
Hernando	44,469	64,341	84,413	102,017	120,258
Hills-borough	646,960	726,863	796,490	861,135	923,090
Indian River	59,896	76,151	92,441	105,941	120,105
Jefferson	10,703	11,632	12,527	13,326	14,093
Lee	205,266	258,918	314,328	357,058	404,042
Levy	19,870	23,240	26,567	29,579	32,488
Manatee	148,442	172,113	194,985	216,936	237,558
Martin	64,014	82,162	100,887	115,967	131,727
Monroe	63,188	68,665	72,278	76,575	79,421
Nassau	32,894	38,627	43,380	49,159	53,983
Okaloosa	109,920	129,130	144,375	155,240	168,073
Palm Beach	576,863	709,550	840,504	953,244	1,070,261
Pasco	193,643	242,242	298,267	341,561	388,769
Pinellas	728,531	804,402	876,599	948,661	1,014,382
St. Johns	51,303	65,866	80,307	92,621	105,238
St. Lucie	87,182	116,106	142,846	167,477	191,824
Santa Rosa	55,988	63,433	70,071	77,892	84,420
Sarasota	202,251	242,162	284,610	318,576	354,570
Taylor	16,532	18,202	19,833	21,200	22,585
Volusia	258,762	306,020	353,517	392,526	433,236
Wakulla	10,887	12,038	13,453	15,030	16,483
Walton	21,300	24,210	27,311	29,725	32,318
Total	7,664,458	8,819,377	9,864,013	10,752,684	11,705,096
Total County	9,746,320	11,242,130	12,623,850	13,838,190	15,052,530
% Coastal	78.6%	74.4%	87.1%	77.7%	77.7%

Source: Governors Office of Planning and Budgeting
(University of Florida Population Projections)

above average densities in the coastal zone of population and structures, these areas are particularly vulnerable to hurricane damage and/or losses.

Economic pressures for coastal development of energy projects have been intensified by the belief of many policy makers that development of such projects are in the national interest. The necessity to reduce American dependence on imported oil accelerates demands to increase domestic exploration and production. Despite discouraging results to date in the exploration for oil off the outer continental shelf, further drilling seems certain, particularly in the gulf states region. Thus, siting of energy facilities in coastal areas will continue to be one of the most hotly contested land use and coastal planning issues in Florida.

Competing issues emerge in the siting process of energy facilities in coastal areas. Air quality constraints, waterfront access and revitalization movements, along with citizen opposition now make the siting process increasingly difficult. Different kinds of energy facilities emit widely varying kinds of pollutants. In some cases, such as nuclear power plants or liquified natural gas (LNG) facilities, the main concern is not with continous emissions, but with the possibility of accidents or damage from a storm event.

Although local government decision-makers are under intense pressure to improve employment and tax revenues in their districts, many are becoming increasingly discriminating about energy facilities as their relative job and tax potentials become clear. Facilities such as storage tank farms that provide very few jobs per acre of land, especially in prime areas like the coastal waterfront, are no longer accepted as net economic assets. In many of these areas, the perceptible move away from the coast for industrial production and toward diversified consumer amenity use, including housing and commerce, conflicts with the pressures for siting of new energy facilities.

D. Facilities Inventory Location Analysis

As stated in the earlier section on population, Florida has experienced tremendous growth in both resident and short-term or tourist population. The central portion of each coast and the southern end of the Florida penisula absorbed most of this growth with the majority of Floridans living in urban areas. Most of these urban dwellers are served by a variety of public services, including public water system and, in some locales, by publicly-owned electric utilities. This tremendous growth pressure and its resulting demand for services will place greater stress on the state's public infrasructure including utility consumption. Thus the demand for energy facilites will continue with coastal sitings being the preferred or ideal location for such facilities. New or expanded energy operations will become subject to coastal hazards in proportion to the frequency of hurricane related storm events.

To provide a listing of those energy facilities in the Coastal High hazard areas an examination of Florida's "Coastal Energy Facility Planning Inventory" and "The 1986 Planners Guide to Power Plant Siting" was used to develop a listing of facilities by Coastal Counties. In addition, inland sites are included as these sites are also affected by major storm related events.

The following section provides a graphic illustration of energy facilities in Florida. Figure 1 shows "Sources of Florida's Energy to the Year 2004." Table 2 provides a listing of Florida's Electric Utility Industry. Figures 2,3, and 4 provides a listing of privately owned utilities, publicly owned and Rural Electric Cooperatives, respectively in Florida. Figure 5 shows the location of coal fired plants in Florida. Figure 6 is a listing of ports and waterways and figure 7 is a location of pipelines and Natural gas facilities in Florida.

E. Historical Storm Analysis

Florida has the unique distinction of being the most vulnerable of all states to the devastating effects of hurricanes and flooding associated with hurricanes. Next to Alaska, Florida has the second longest coastline of any state in the union, consisting of 1,350 miles of low-lying coastline and numerous tidal inlets. This, coupled with its unique southern position and the fact that the state is a peninsula surrounded by the Gulf of Mexico and the Atlantic Ocean, make Florida extremely vulnerable to the effects of hurricanes.

As rapid development continues to occur along Florida's coast, the potential for a major disaster as a result of the state's vulnerability increase each year. It is estimated that over seven million persons reside in the coastal areas of the state, the overwhelming majority of whom have never experienced the effects of a hurricane.

Figure 1

Sources of Florida's Energy, 2004. Source: FCG 1985 Aggregate Information. Note: Qualifying Facilities (QF) Include Hydroelectric, Cogeneration and Small Power Producers.

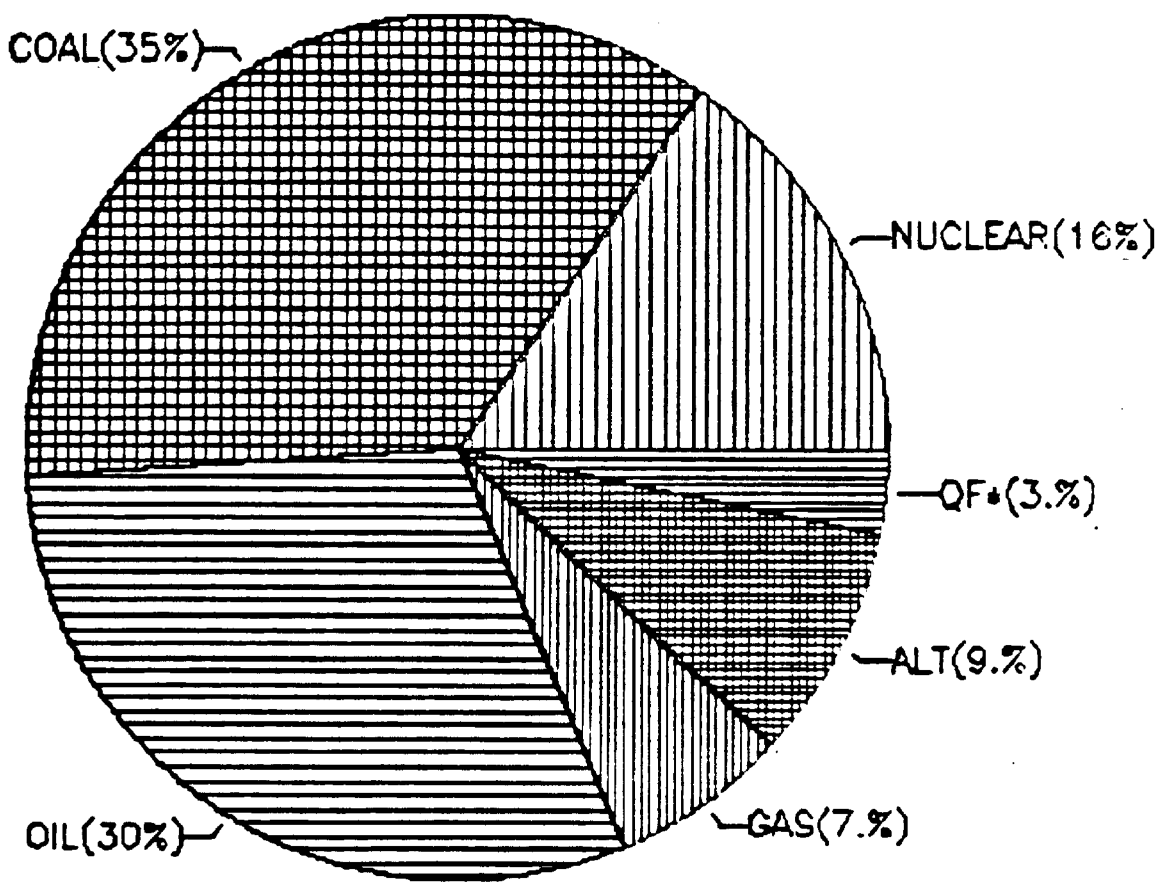


Table 2

FLORIDA ELECTRIC UTILITY INDUSTRY

Investor Owned Systems (All Generate)

1. Florida Power & Light
2. Florida Power Corporation
3. Florida Public Utilities
4. Gulf Power Company
5. Tampa Electric Company
6. Reedy Creek Util. Co., Inc.

Generating Municipal Systems

1. Ft. Pierce
2. Gainesville/Alachua
3. Homestead
4. Jacksonville
5. Key West
6. Kissimmee
7. Lakeland
8. Lake Worth
9. New Smyrna Beach
10. Orlando
11. St. Cloud
12. Sebring
13. Starke
14. Tallahassee
15. Vero Beach
16. Wauchula

Generating Rural Electric Cooperatives

1. Florida Keys

Generating - Other

1. Southeastern Power Administration
   (Jim Woodruff Dam)

Nongenerating Municipal Systems

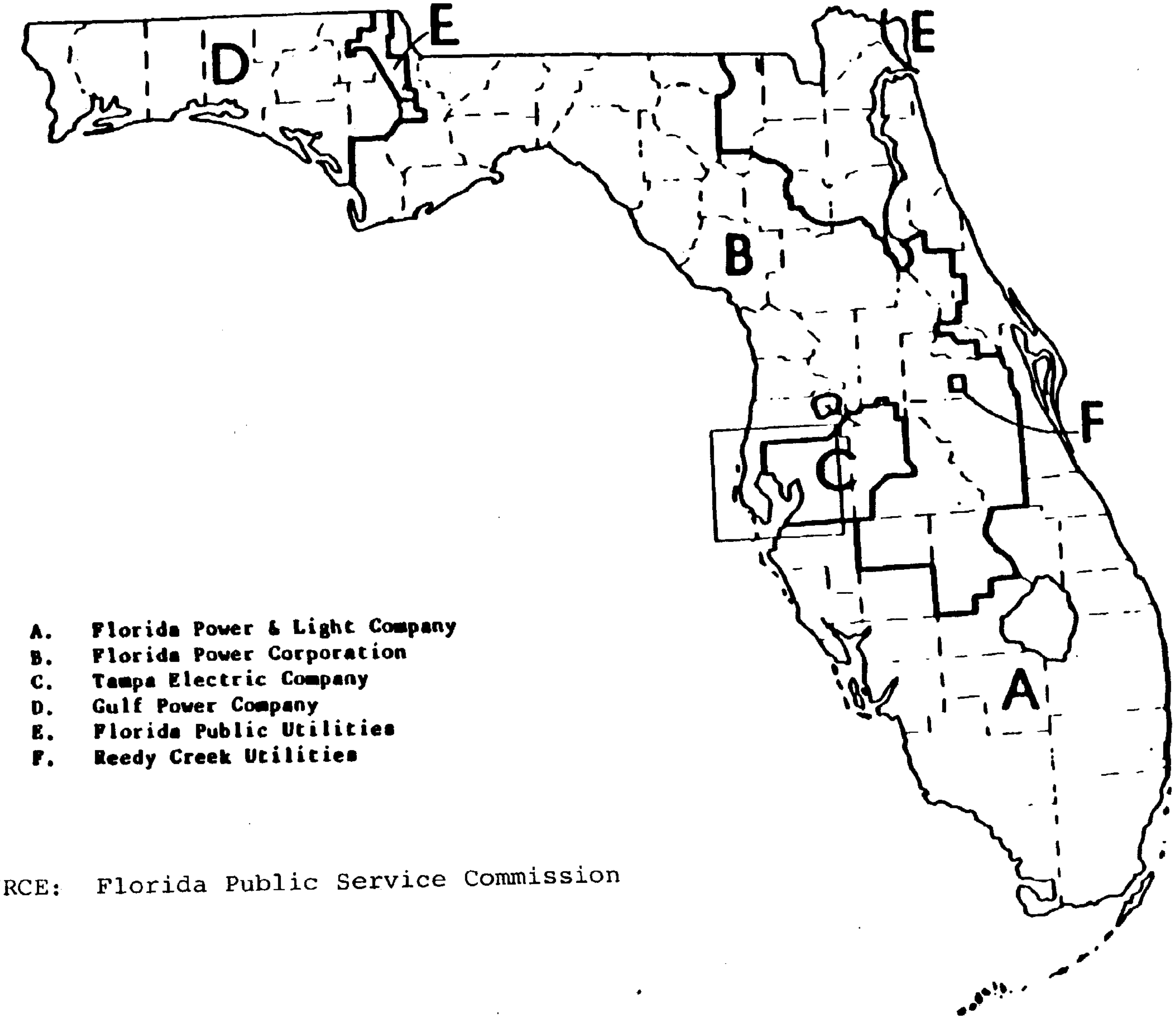
1. Alachua
2. Bartow
3. Blountstown
4. Bushnell
5. Chattahoochee
6. Clewiston
7. Fort Meade
8. Green Cove Springs
9. Havana
10. Jacksonville Beach
11. Lake Helen
12. Leesburg
13. Moore Haven
14. Mount Dora
15. Newberry
16. Ocala
17. Quincy
18. Williston

Nongenerating Rural Electric Cooperatives

1. Central Florida
2. Choctawhatchee
3. Clay
4. Escambia River
5. Glades
6. Gulf Coast
7. Lee County
8. Peace River
9. Sumter
10. Suwannee Valley
11. Talquin
12. Tri-County
13. West Florida
14. Withlacoochee River
15. Okefenokee
16. Alabama

SOURCE: 1980 Florida Energy Fact Book

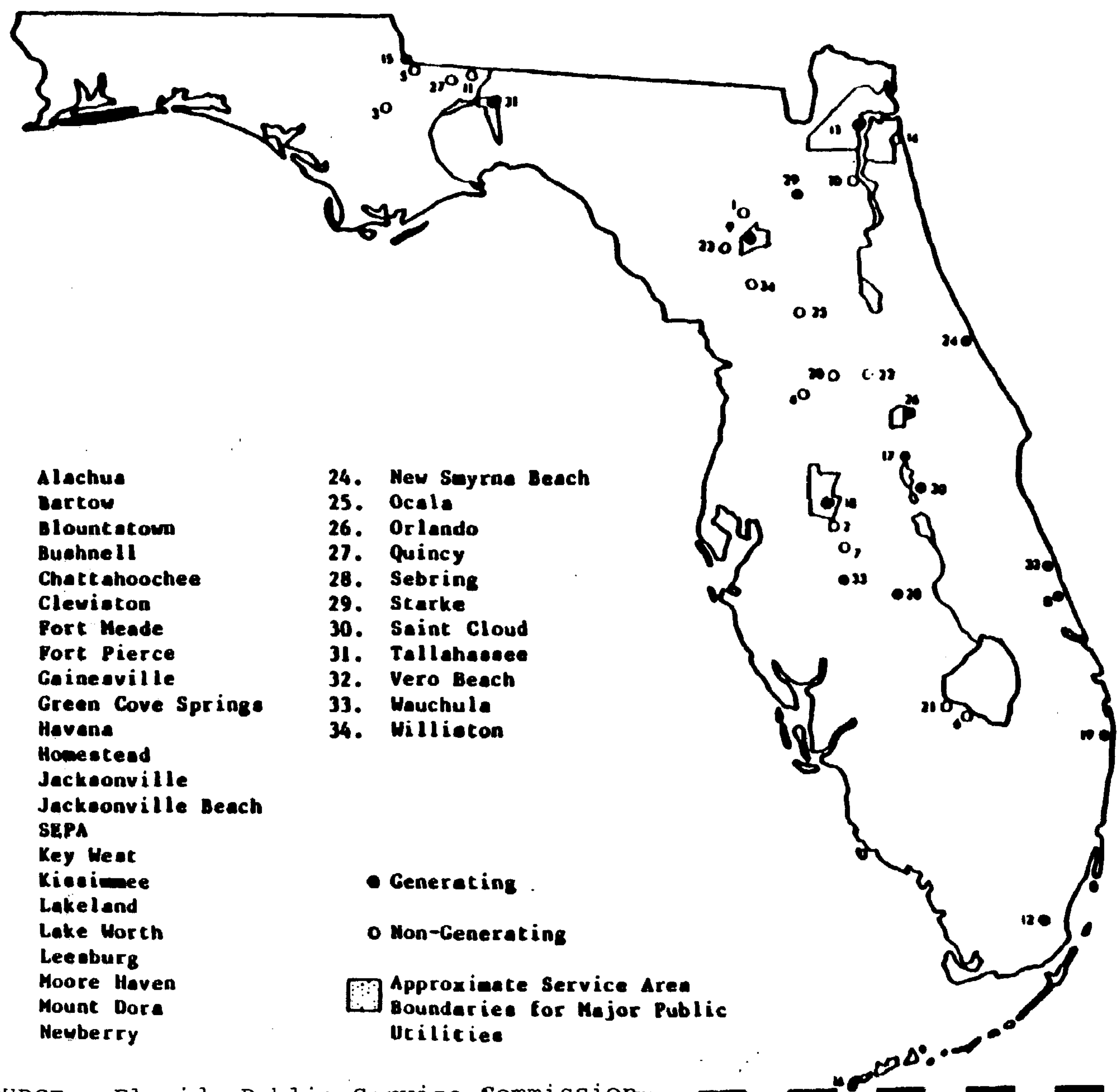
Figure 2
PRIVATELY OWNED UTILITIES



SOURCE: Florida Public Service Commission

Figure 3

PUBLICLY OWNED UTILITIES



1. Alachua
2. Bartow
3. Blountstown
4. Bushnell
5. Chattahoochee
6. Clewiston
7. Fort Meade
8. Fort Pierce
9. Gainesville
10. Green Cove Springs
11. Havana
12. Homestead
13. Jacksonville
14. Jacksonville Beach
15. SEPA
16. Key West
17. Kissimmee
18. Lakeland
19. Lake Worth
20. Leesburg
21. Moore Haven
22. Mount Dora
23. Newberry
24. New Smyrna Beach
25. Ocala
26. Orlando
27. Quincy
28. Sebring
29. Starke
30. Saint Cloud
31. Tallahassee
32. Vero Beach
33. Wauchula
34. Williston

● Generating

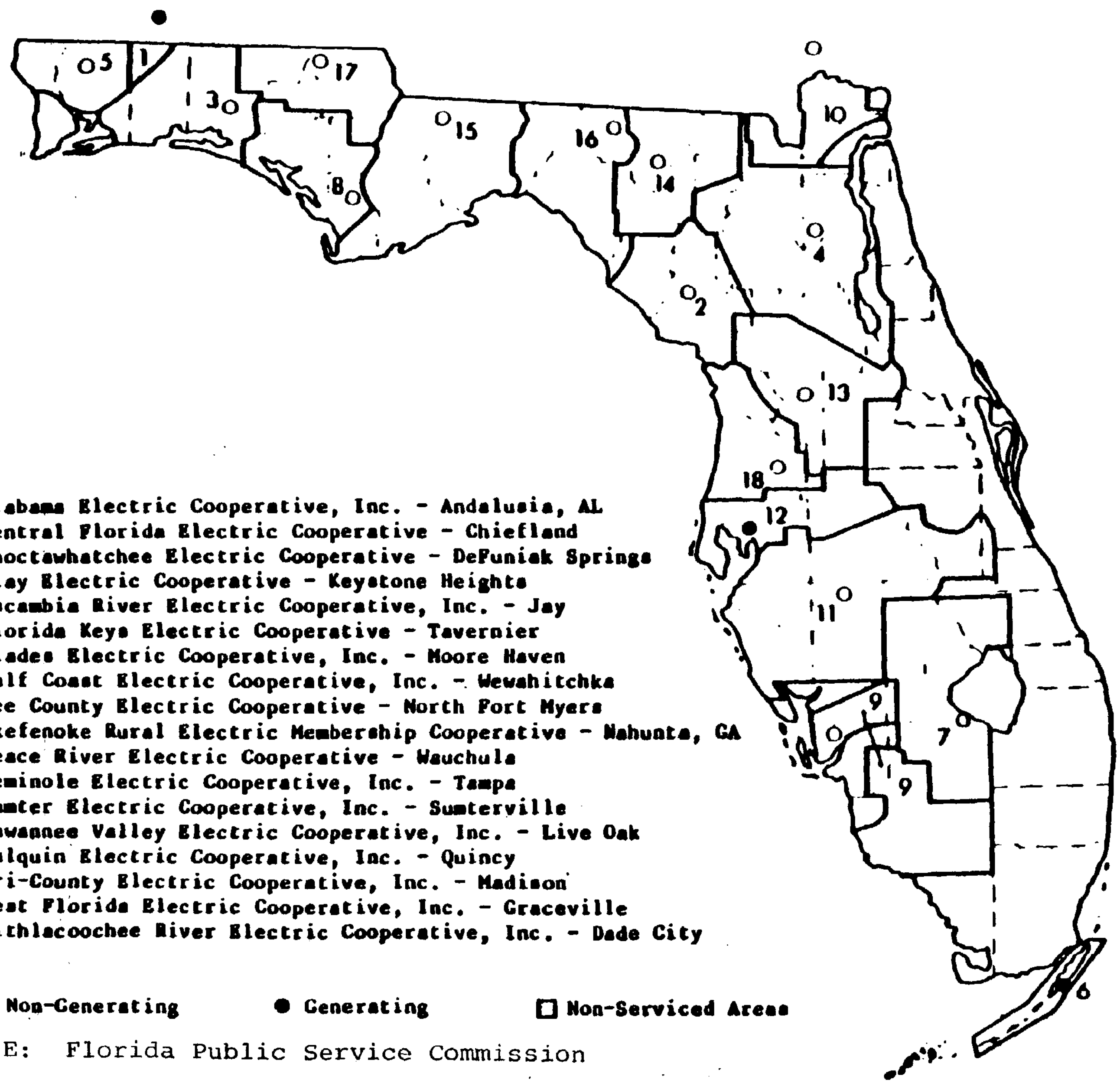
○ Non-Generating

Approximate Service Area Boundaries for Major Public Utilities

SOURCE: Florida Public Service Commission

Figure 4

RURAL ELECTRIC COOPERATIVES



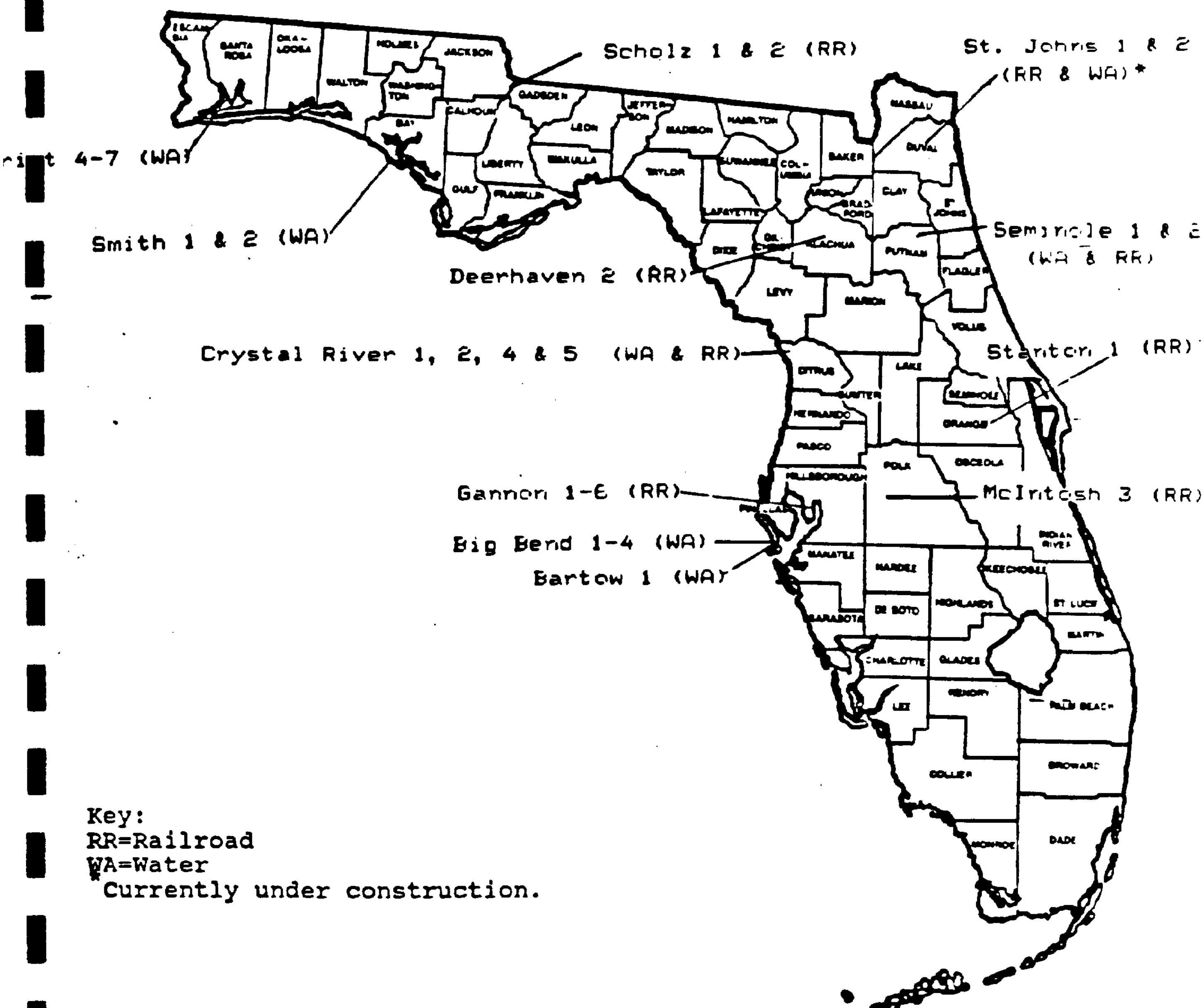
1. Alabama Electric Cooperative, Inc. - Andalusia, AL
2. Central Florida Electric Cooperative - Chiefland
3. Choctawhatchee Electric Cooperative - DeFuniak Springs
4. Clay Electric Cooperative - Keystone Heights
5. Escambia River Electric Cooperative, Inc. - Jay
6. Florida Keys Electric Cooperative - Tavernier
7. Glades Electric Cooperative, Inc. - Moore Haven
8. Gulf Coast Electric Cooperative, Inc. - Wewahitchka
9. Lee County Electric Cooperative - North Fort Myers
10. Okefenoke Rural Electric Membership Cooperative - Nahunta, GA
11. Peace River Electric Cooperative - Wauchula
12. Seminole Electric Cooperative, Inc. - Tampa
13. Sumter Electric Cooperative, Inc. - Sumterville
14. Suwannee Valley Electric Cooperative, Inc. - Live Oak
15. Talquin Electric Cooperative, Inc. - Quincy
16. Tri-County Electric Cooperative, Inc. - Madison
17. West Florida Electric Cooperative, Inc. - Graceville
18. Withlacoochee River Electric Cooperative, Inc. - Dade City

○ Non-Generating ● Generating □ Non-Serviced Areas

SOURCE: Florida Public Service Commission

Figure 5

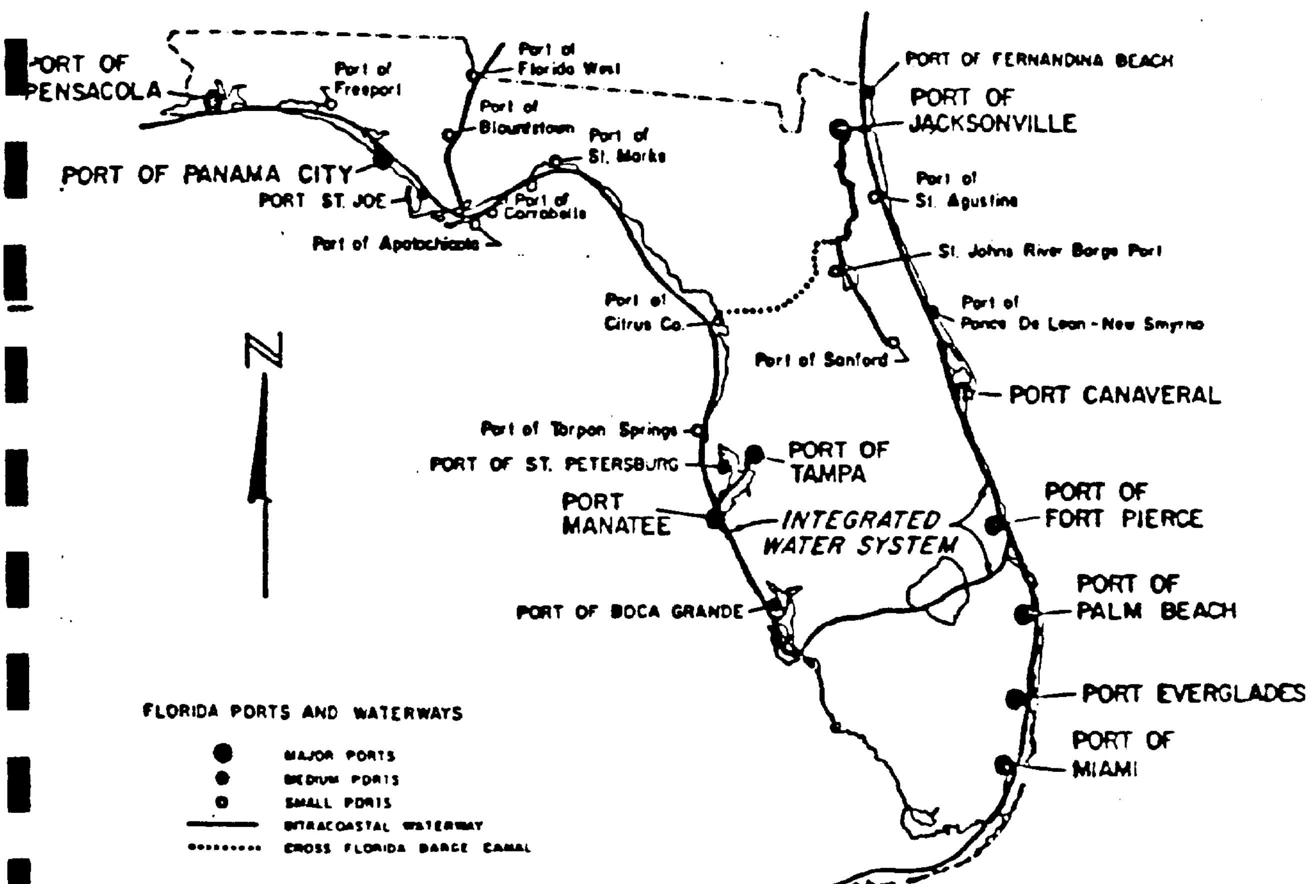
Location of Coal-Fired power Plants in Florida with Primary Coal Supply Methods. Sources: FCG Aggregate Information and 1986 TYSPs.



Key:
RR=Railroad
WA=Water
*Currently under construction.

Figure 6

Ports and Waterways of Florida. Source: PSC (1980).



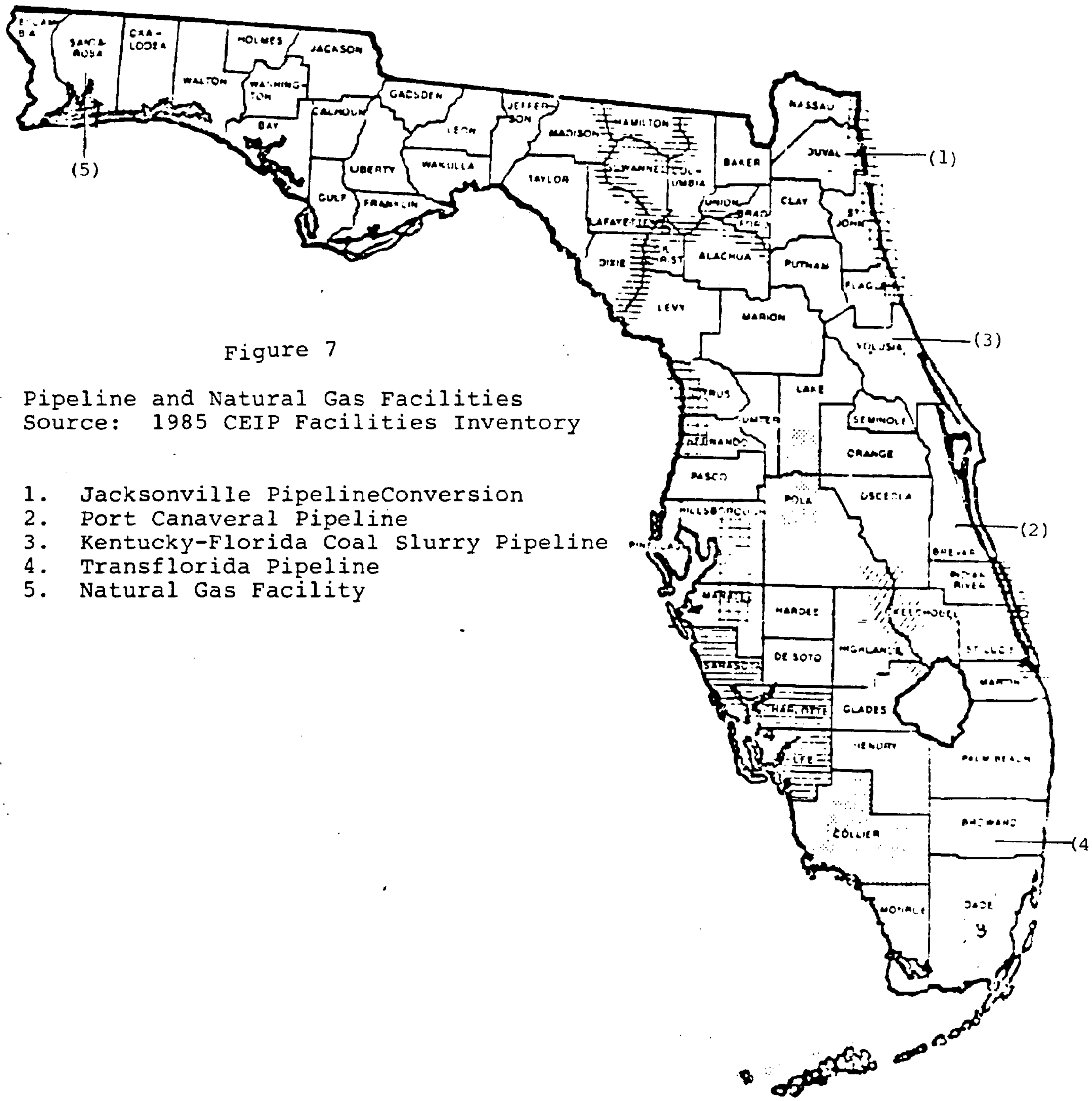


Figure 7

Pipeline and Natural Gas Facilities
Source: 1985 CEIP Facilities Inventory

1. Jacksonville PipelineConversion
2. Port Canaveral Pipeline
3. Kentucky-Florida Coal Slurry Pipeline
4. Transflorida Pipeline
5. Natural Gas Facility

A hurricane is defined as a tropical cyclone in which winds reach constant speeds of 74 miles per hour or more, and blow in a large spiral around a relatively calm center. Hurricanes are simply giant whirlwinds that normally move from the southeast to the northwest but are, for the most part, unpredictable in nature. Near the center, hurricane winds may gust to more than 200 miles per hour.

The hurricane "season" or period of greatest possibility of occurrence, is from June through November when the ocean temperatures are warmest. The Gulf of Mexico's coastline is more vulnerable than the Atlantic coast to early season hurricanes since they usually form in the western Carribean and Gulf of Mexico. Late storms are fairly well distributed along the gulf and Atlantic coastlines.

The three greatest threats in a hurricane are: storm surge; wind damage, with the possibility of associated tornadoes; and inland flooding. Storm surge is hurricane's worst killer and poses the greatest threat to energy facilities sited in coastal high hazard areas. Storm surge is a general rise in sea level that begins over the deep ocean. The low pressure and strong winds around a hurricane's eye raise the ocean surface a foot or two higher than the surrounding ocean surface, forming a dome of water that may be as much as 50 miles across. As the storm moves into shallow coastal waters, decreasing water depth transforms the dome into a storm surge that can rise 20 feet or more above normal sea level and cause massive destruction along shorelines in its path.

Throughout the State, the vulnerability of population and property to flood-related damage is increasing. Florida's rapid population growth has pushed development into several high-risk areas along the coatal zone.

Historically, Florida has experienced a high incidence of flooding. Floods have, and continue to be, one of the most destructive and costly natural hazards occuring in the State, particularly when associated with "wet" hurricanes (storm surge and upwards of 12 inches of rainfall).

Table three (3) examines the most notable floods and flood control projects in the state and Table four (4) examines some devastating hurricanes of the 20th century which have struck Florida.

TABLE 3.

FLOODS AND FLOOD CONTROL IN FLORIDA, 1900-1985

Date	Event
1905	First drainage acts passed by Florida Legislature.
1910	Canal construction begins near Lake Okeechobee and the Everglades.
1913	General Drainage Act
1921	October - Tropical storm moves inland near Tarpon Springs.
1926	September - Category 4 hurricane moves inland at Miami and passes over Lake Okeechobee. Clewiston is swept by floodwaters from the lake.
1928	September - Hurricane moves inland at Palm Beach and passes over Lake Okeechobee. A 12-foot wind-generated tide sweeps Belle Glade.
1929	March - Heavy rains cause Apalachicola River to overflow. At Chattachoochee, the river exceeds its 100-year flood elevation.
1933	September - Hurricane moves inland at Vero Beach Hillsborough County experiences 50-year flood elevations.
1935	September - "Labor Day" Hurricane sweeps the Florida Keys.
1941	October - Tropical storm passes over Trenton.
1944	October - Hurricane crosses the Dry Tortugas, moves inland near Ft. Myers and exits near Jacksonville.
1945	August - Tropical storm causes major flooding in Tampa Bay area. September - Hurricane moves inland near Miami.

1947	September and October - Two hurricanes cross South Florida.
	January to December - Miami receives 102 inches of rainfall (58 inches is annual norm). Flooding along Kissimmee River.
1948	September - Hurricane crosses South Florida
	Legislature creates the Central and South Florida Flood Control District. Everglades National Park is created.
1950	September - Hurricane Easy hits Cedar Key. Damage along the west coast is extensive.
1953	August and September - Highlands County and vicinity receives 22 inches of rainfall in 24 hours.
1957	September - Embankment failure at Lake Talquin precipitates Ochlockonee River Flood.
	Water Resources Act passed.
1959	Severe flooding in Tampa area.
1960	March - Severe storm affects Central and Southwest Florida.
	September - Hurricane Donna (Category 4) crosses the Keys and moves inland at Ft. Myers.
1964	August - Hurricane Cleo moves inland near Vero Beach.
	August - Hurricane Dora moves inland at St. Augustine and crosses Northeast Florida.
1966	June - Tropical storm affects Central and North Florida.
1967	Florida Air and Water Pollution Control Act.
1969	September - The Quincy-Havana area receives 20 inches of rainfall during a three-day period. The Ochlockonee River and several creeks exceed 100-year flood elevations.

1972	June - Hurricane Agnes moves inland at Panama City.
	Land Conservation Act; $240 million bond issue for land acquisition approved in referendum.
	Water Resources Act passed. Five regional water management districts are created.
1975	September - Hurricane Eloise moves inland near Panama City.
1979	Conservation and Recreation Lands Program (CARL).
1979	May - Hurricane David moves up Florida's east coast.
1981	September - Hurricane Frederic hits Florida's west coast.
	Save Our Coast $200 million bond issue land acquisition program initiated.
	Water Management Lands Trust Fund SAVE OUR RIVERS program initiated.
1982	June - A subtropical storm (No-Name Storm) moves inland near Yankeetown and crosses Central Florida.
1983	Warren S. Henderson Wetland Protection Act.
1985	Comprehensive Growth Management Bill.
	September - Hurricane Elena hits Cedar Key, extensive damage to Pinellas, Franklin and Levy Counties.
	November - Hurricane Kate delivers knockout blow to Franklin, Gulf and Wakulla Counties. Devastating late season storm.

Source: Florida State University, Water Resources Atlas of Florida. Florida Resources and Environmental Analysis Center; Tallahassee, Fl. 1984.

TABLE 4

FLORIDA HURRICANES OF THE 20TH CENTURY

Source: DCA Division of Emergency Management

Date		Area Most Affected	Name
June	1916	Pensacola	
Sept.	1919	Sand Key	
Sept.	1926	Miami, Pensacola	
Sept.	1928	Lake Okeechobee	
Aug.	1933	Jupiter, Vero Beach	
June	1934	Panhandle	
Sept.	1935	Tampa, Southern Florida	Labor Day Storm
Oct.	1935	Miami, Southern Florida	
Oct.	1944	Dry Tortugas	
Sept.	1945	Miami	
Sept.	1947	Middle Florida	
Oct.	1947	Southern Florida	
Sept.	1948	Key West	
Oct.	1948	Southern Florida	
Aug	1949	West Palm Beach	
Sept.	1950	Cedar Key	Easy
Oct.	1950	Miami	King
Sept.	1956	Northern Florida	Flossy
Sept.	1960	Ft. Meyers, South Florida	Donna
Aug.	1964	Miami, South Florida	Cleo
Sept.	1964	St. Augustine	Dora
Oct.	1964	South Florida	Isabell
Sept.	1965	South Florida	Betsy
June	1972	North Florida	Agnes
Nov.	1984	Palm Beach East Coast	Thksg. Day Storm
Sept.	1975	North Florida	Eloise
May	1979	East Coast	David
Sept.	1981	Panama City	Fredrick
June	1982	Yankeetown	"No-Name Storm"
Sept.	1985	Cedar Key	Elena
Nov.	1985	Panhandle	Kate

All hurricanes are to be considered dangerous. However, some are considered to have greater destructive potential than others. For this reason, hurricane forecasters have adopted a disaster-potential scale, termed the Saffir-Simpson Hurricane Scale, in which hurricane intensity has been divided into several categories based on specific hurricane examples. The criteria delineating these categories are included in Table five.

TABLE 5

SAFFIR-SIMPSON HURRICANE SCALE

Source: DNR Division of Beaches and Shores

CATEGORY	WIND MPH	STORM SURGE	CENTRAL PRESSURE	DAMAGE
1	74-95	4-5	> 28.94	minimal
2	96-110	6-8	28.50-28.91	moderate
3	111-130	9-12	27.91-28.47	extensive
4	131-155	13-18	27.17-27.88	extreme
5	> 155	> 18	< 27.17	catastrophic

Force elements generated by hurricanes that act on the shoreline upon impact are waves, winds, and storm surge associated hydraulic forces. Applicability and ranges of influence of each of the force categories are illustrated in Figure 8. The destructive potential of waves in the vicinity of coastal structures such as power plants, particularly at breaking or peaking as illustrated in Figure 8 is to be particularly emphasized. For this reason the Saffir-Simpson Hurricane Scale (Table five) has been extended to include a column for wave forces. For exposed shore-fronting structures, and under most conditions, forced waves resulting from hurricanes are probably more destructive than either wind forces, or the current forces occuring within the storm surge.

When a storm surge approaches the shoreline across shoaling water it causes a rise in nearshore water level due to wind stresses. This departure from the normal water level is called storm surge. This rise in water can lead to flood damage to energy facilities due to inundation and hydrostatic pressures. Currents occuring within the storm surge can also produce significant hydrodynamic pressures on

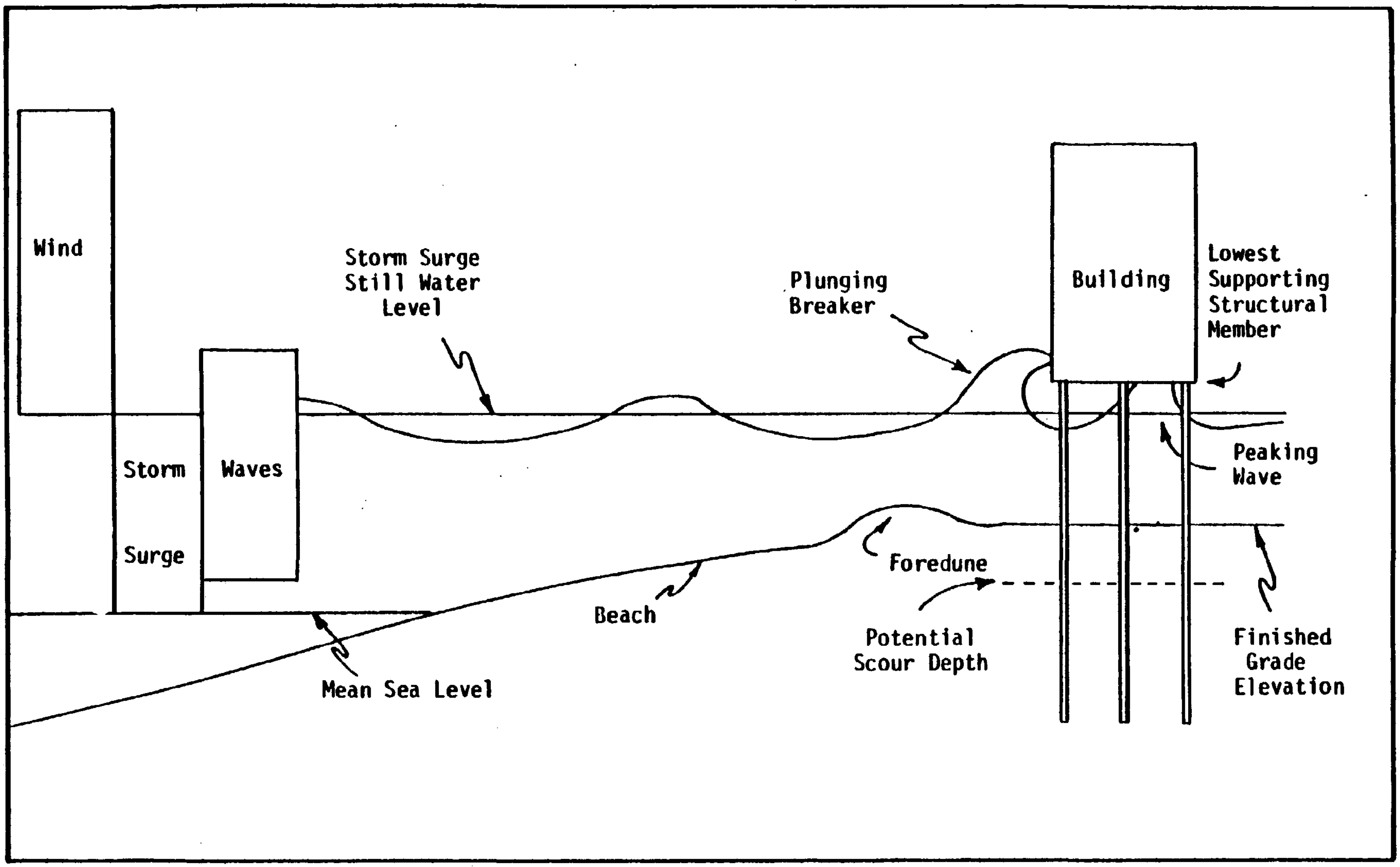


Figure 8 Cross-section of the littoral zone showing the three categories of hurricane generated forces and the vertical extent of influence.
SOURCE: DNR Division of Beaches and Shores

facilities structures and result in scour leading to structural damage. The storm surge is also very important, since it is the superelevated surface across which the unusually high storm generated waves propagate. The storm surge parameter is commonly used as an indicator of hurricane intensity.

III. Structural Analysis

Permitting of energy facilities in coastal high hazard areas which are subject to damage or destruction by a hurricane or other hazardous storm event is addressed in land use regulations of local governments. Specific criteria for development, siting, and redevelopment are expressed in the "Local Government Comprehensive Planning and Land Development Regulation Act", Chapter 163.3161 and Chapter 163.3178, the "Coastal Management" element.

The legislative intent to protect the fragile coastal environment is embodied in the language which states in part:

> ...in the event of a natural disaster, the state may provide financial assistance to local governments for the reconstruction of roads, sewer systems, and other public facilities. Therefore, it is the intent of the Legislature that local government comprehensive plans restrict development activities where such activities would damage or destroy coastal resources, and that such plans protect human life and limit public expenditures in areas that are subject to destruction by natural disasters.

> ... Each coastal management element shall be based on

studies, surveys, and data; be consistent with coastal resource plans and prepared and adopted pursuant to general or specific law and contain:

... a land use and inventory map of existing coastal uses and areas subject to coastal flooding.

... an analysis of the envirnmental, socioeconomic, and fiscal impact of development or redevelopment proposed in the future land use plan, with required infrastructure to support this development or redevelopment, on the natural and historical resources of the coast and the plans and principals to be used to control development or redevelopment to eliminate or mitigate the adverse impacts on coastal wetlands and other fragile coastal resources.

... a component which outlines principles for hazard mitigation in the event of an impending natural disaster.

... a redevelopment component which outlines the principles which shall be used to eliminate inappropriate or unsafe development in the coastal areas.

... a shoreline use component which identifies public access to beach and shoreline areas and addresses the need for water-dependent and water-related facilities along shorelines.

... designation of high-hazard coastal areas, subject to destruction or severe damage by natural disasters.

... an identification of regulatory and management techniques to control development or redevelopment.

A. Building Codes and Coastal Construction Regulations

Protecting the public from faulty construction and engineering practices led to the creation of the first building codes and ordinances. With the advent of the industrial age and subsequent change from an agrarian to an urbanized society, building codes have envolved into complex documents that cover a wide range of hazards. However, the basic rational for a building code remains intact--to protect the health, safety, and general welfare of the public as it relates to the construction and occupancy of buildings and structures.

The basic purpose of a building code is to regulate those aspects of building construction necessary for the protection of persons who have no voice in the matter of construction and arrangement of buildings with which they came into contact. A typical building code regulates the construction, alteration, maintenance, repair, and demolition of buildings and structures (Sanderson, 1973).

This is accomplished by establishing a set of minimally acceptable conditions or standards for nearly all phases of building construction.

Building codes are commonly classified as either performance or specification oriented codes. A performance code recommends an objective to be accomplished and allows broad leeway to designers in selecting the materials and methods that would achieve the desired results. In contrast to the performance code, a specification code describes in detail exactly what materials are to be used, the size and spacing of units, and the methods by which they are assembled (Sanderson, 1973).

All of the national model building codes used in some form or another by local jurisdictions are considered by their organizations to be performance oriented. In reality they are a combination of standard specification and performance requirements. The specification aspect of these codes usually lies in the areas of the quality of materials selected and the manner in which they are used. These two aspects are governed by material standards and established engineering design criteria, both of which are specification documents (Sanderson, 1973).

Coastal Construction Regulation

Construction of habitable and non-habitable structures in the coastal high hazard area is regulated by a variety of regulations including:

- coastal flood hazard area permit regulations
- zoning regulation with special provision for coastal areas.
- subdivision regulations with special provisions for coastal hazard areas
- building codes
- coastal construction code

Some of these regulations affect coastal construction; others affect a range of coastal activities.

In addition to local building requirements, the State of Florida regulates construction in coastal areas through its Coastal Construction Code and Coastal Construction Control line. These two regulatory programs provide additional protection to property in high hazard coastal areas through stringent building standards and limitations on construction in areas subject to flooding and severe wave forces in addition to wind forces.

The coastal construction code is an instrument that combines zoning and minimum standards for the design and construction of habital and non-habitable structures in coastal areas. Standards within the code are intended to address design features which affect the structural stability of the structure under design storm conditions.

The 140 mile per hour design wind criterion for the 100-year extreme climatological event adopted by the State of Florida pursuant to Chapter 161, Florida Statures (F.S.), and set forth in Chapter 16B-33 Florida Administrative Code (F.A.C.), is based on work conducted by the Division of Beaches and Shores, Florida Department of Natural Resources. The 140 mph design wind speed is applicable only at the shoreline. Under normal conditions Florida mean sea level (MSL) only slightly departs from National Geodetic Vertical Datum (NGVD)....i.e., less than 0.5-feet on the average. However, during extreme strom event impact, the shoreline attains elevations characteristic of the storm tide elevation. For this reason, Coastal Construction Control Lines (CCCL) are established and periodically reviewed pursuant to Section 161.053, FS, to locate the upland extent of significant hydraulic effects of the 100-year storm event (Balsillie et al., 1983).

Energy facilities in the coastal area are defined as "Nonhabitable Major Structures" and are subject to coastal construction requirements with the specific exemption of electrical power plants. All other facilities are subject to design criteria which addresses structural requirements for building in the coastal zone.

The effect of hurricane wind forces on buildings and structures (inclusive of energy facilities) are addressed in structural requirement and design parameters for development and are based on the design wind speed, expressed as velocity pressure in pounds per square foot.

All of the model codes in use in Florida, including the Standard Building Code and the South Florida Building Code define some wind speed design but the approach differs. The South Florida Building Code requires that buildings be designed and constructed to resist forces due to winds of not less than 120 miles per hour. The 1986 revisions to the 1985 Standard Building Code uses a minimum fastest-mile wind velocity of 110 or 115 mph as appropriate. All construction occurring in the Florida Keys uses a minimum design speed of 115 mph.

The problem with these design values is that they may well be below the wind forces impacting on structures in coastal locations. The wind speed values are based on collection of historical wind speed data which is typically collected at airports. However, most airports are not located in areas where the wind forces are at their highest intensity. Usually the maximum wind velocity cause by a hurricane is sustained for a few hundred yards inland from the coast. Beyond this distance, the wind velocity decreases considerably due to the frictional drag caused by surface features (Balsillie, 1978). It has been determined that when 105-110 mph winds are recorded 5 to 10 miles inland, the speed at the shoreline would be somewhere between 137 and 143 mph (Balsillie, 1978). Hence, wind speeds used for design purposes are not representative of the wind forces encountered at the shoreline where the frictional effects are significantly less.

Other factors influence the ability of buildings to withstand the pressures exerted on them by wind forces. These include the height of the building, the shape of the building, and the height and location of surrounding buildings.

B. <u>Coastal Zone Protection Act</u>

During the 1985 legislative session, this legislature enacted the "Coastal Zone Protection Act of 1985". The specific intent of the legislature was "..._ that the most sensitive portion of the Coastal area shall be managed through the imposition of strict construction standards in order to minimize damage to the natural environment, private property, and life (S.161.535), Florida Statutes)... The legislature further declared that the most sensitive portions of the coastal area, for purposes of this law were within a designated "Coastal Building Zone"

This building zone was defined graphically in three ways:

1) For mainland areas fronting upon the open ocean in which a coastal construction control line (CCCL) had been established, the building zone was the land area from seasonal high-water line to a line 1500 feet landward from the CCCL. This include primarily

sandy beach areas such as Jacksonville Beach, Fort Lauderdale and Pensacola Beach among others.

2) For mainland areas fronting upon the open ocean in which a CCCL had not been established, the building zone was the land area 3000 feet landward from the mean high-water line. This include the marshy, non-sandy shoreline from Wakulla County South to Pasco County, as well as Monroe County and the Florida Keys. For these areas, the Department of Community Affairs (DCA) was to establish the coastal building zone. DCA was further charged with delineating the zone by survey and monument.

3) For areas defined as "Coastal Barrier islands" the building zone is the land area 5000 feet landward of the CCCL. This includes areas such as Santa Rosa Island, Treasure Island, and Sanibel Island.

Within these coastal buildings zones increased construction standards were imposed which included:

-- Design and construction of structures to withstand a wind velocity of no less than 140 miles per hour, including consideration of internal pressures on internal walls, cellings and floors resulting from damaged windows or doors. Mobile home construction standrds are requlated by the federal government; therefore, they were exempted from this requirement;

-- Elevation of structures, both residential and commerical, above design breaking wave crest superimposed on the storm surge of a 100-year storm;

-- Construction of buildings foundations to resist all anticipated loads resulting from a 100-year storm event including erosion and wave scour forces; and

-- Prohibition of substantial walls or partitions constructed beneath an elevated structure.

Essentially, these are the same buildings standrds found in chapter 16B-33, Florida Administrative Code, which regulates construction seaward of the CCCl. The state charged local governments with adopting and enforcing these new standards as part of their building code.

Several problems and considerable confusion arose surrounding the new building requirements as expressed in the "model" coastal building code. These included:

--Lack of consistency between federal flood insurances regulations and the new state requirements. All but two local governments within the state participate in the National Flood Insurance Program. Of particular concern was the requirements that commercial structures, such as service stations, convenience stores, supermarkets, etc., be elevated instead of floodproofed. Federal regulation allowed floodproofing in lieu of elevation while state coastal building requirements did not;

-- Inability to determine the coastal building zone for those areas in which a CCCL had not been established.

--The 140 mile per hour windspeed requirement was not conducive to application under standard building code practice. For design purposes, windspeeds are converted into pressures acting upon a structure. When determining pressures, the design professional applies different variables and coefficients based upon the type and shape of the structure. Generally, this process results in a structural design which is greater than the baseline windspeed criteria. When applying these variables and coefficient to a baseline windespeed of 140 miles per hour, the design pressures and resulting construction costs were dramatically increased.

It was further determined that there have been no recorded failures of properly engineered and designed structures from wind damage prior to establishing the 140 mile per hour requirements. Generally the main causes of building failures during a coastal storm are flood and wave damage aggravated by improper building construction and inspection methods, primarily in one and two family structures. In this regard, it was questionable as to whether the 140 mph requirement was either necessary or reasonable.

-- The design and construction requirements for foundations include erosion computations due to wave and scour forces acting upon the foundation. The majority of structural engineers and architects are unfamiliar with these types of computations, which are normally the exclusive specialty of coastal engineers. As a further problem, these computations were required for structures throughout the coastal building zone, even in areas not subject to wave and scour forces.

Problems concerning the definition and identification of coastal barrier islands, conflicting references to building codes and other minor problems were also encountered. However, the main problem appeared to be that rule language in Chapter 16B-33, Florida Administrative Code, designed for interpretation and application by state coastal engineers, was enacted into statutory language for interpretation by local building officials, design professionals and others.

To correct the problems associated with the 1985 legislation relative to coastal building codes, the 1986 session enacted into law the following changes:

-- The definition of coastal building zone for areas in which a CCCL had not been established was changed from 3000 feet landward of the mean high-water line to the land area seaward of the most landward Velocity Zone (V-Zone) as shown on flood insurance rate maps (s. 161.54(1), F.S.);

-- The elevation requirements for residental and commerical structures were made consistant with federal flood insurance regulations. As a result of this change, all major structures are required to be designed, constructed and located in compliances with federal flood insurance ordinaces, whichever is more restrictive. This action resolved inconsistencies with definitions and terms between federal regulations and state law, permitted of commerical structures rather than required elevation. (S.161.55 (1)(b) and (c), F.S.);

-- The 140 mile per hour windspeed requirement was adjusted reduced the baseline windspeed from 140 miles per hour to 110 miles per hour, except for the Florida Keys which has a baseline windspeed of 115 mph. Velocity was redefined as fastest mile-wind for application to Section 1205 of the 1986 revisions to the 1985 Standard Building Code. This section of the code provides specific pressures, heights and coefficients for use in building design. This method of calculation for construction design was developed by the American National Standards Institute and is considered state-of-the-art with regard to windloads (S.161.55(d), F.S.);

-- Another important change involved applicability of erosion and scour computations for foundation design. The 1985 requirements were applicable to foundation design for major structures throughout the coastal building zone, even for structures located in areas not subject to wave scour and erosion forces. This was done primarily to address problems with slab-on-grade construction which directly abutted the CCCL in counties for which the CCCL had not been resurveyed since June 30, 1980. For 1986, these erosion and scour computations are required only in counties for which the CCCL has not been resurveyed since June 30, 1980. Counties in which the CCCl has been resurveyed are exempted from this requirement (S.161.55(1), F.S.);

-- Most of the 1985 language concerning elevation of structures was deleted. Those requirements are addressed as part of federal flood insurance regulations adopted by references in S.161.55(1)(c), F.S. (Jernigan, 1986).

C. Hazard Mitigation

The purpose of any emergency management effort at the state or local level is to enhance the public safety by protecting life and property in the event of a natural or man-caused hazard. Although efforts to prepare for, respond to, and recover from such events enhance the public safety on a short-term basis, the effectiveness and efficiency of these efforts is significantly affected by the manner in which the public and private sectors manage the location, use, and design of human systems and activities. Therefore, the only way to adequately protect the public from natural and other disasters is through long-term hazard mitigation programs.

Generally speaking, hazard mitigation programs will include state and local-level activities which avoid or reduce the probability of a disaster occurrence. The need to incorporate hazard mitigation as part of the state's emergency management effort has increased in recent years because of (1) the rising public and private costs of recovering from disasters,

(2) a growing concentration of people and structures in hazardous areas, and (3) the recurrence of disasters particularly in high risk coastal zone areas. Furthermore, mitigation activities may be necessary to reduce the vulnerability of communities which will result from present and future growth policies and development practices.

Land use decisions, construction practices, and transportation and economic development should be accomplished in a manner which does not promote disaster potential or diminish the ability of responsible state and local entities to provide for the public safety in emergency or disaster situations.

While it would be ideal to mitigate all hazards that pose a threat to Florida, the primary focus of the state's hazard mitigation effort is predictable, recurring hazards. At a minimum, this would include activities to mitigate water and erosion impacts associated with riverine and flash floods, and wind impact associated with hurricanes and coastal storms.

Mitigation can be accomplished by using any of the following three basic approaches in an effective and coordinated manner: (1) it can act on the hazard itself; (2) it can act on or modify the human systems and activities which are damaged by the hazard; and (3) it can act directly on the interaction of the hazard and the human systems and activities which are in jeopardy. Implicit in the second and third approaches are actions which modify the economic and social impact of the hazard (e.g., providing insurance), and actions that modify human behavior so that they and their structures are less likely to be harmed (e.g. the use of higher wind speed design criteria for energy facilities in coastal high hazard areas).

Activities that relate to the first approach (to modify the hazard itself) are frequently called structural measures. These measures will usually be part of a comprehensive hazard mitigation program in situations where the hazard area is developed and the relocation of people and their activities is economically or politically impractical. The other two approaches can use non-structural measures such as relocation of facilities, construction codes, and land use regulation, to name a few.

Hazard mitigation can be viewed as long range planning to prevent persons and property from ever becoming vulnerable to the hazard in the first place. Mitigation efforts can usually be incorporated into a local government's comprehensive planning program. Examples of these efforts are floodplain zoning, wind-resistant building codes, industrial safety codes, coastal construction control lines, and dune protection ordinances. Mitigation efforts also can be undertaken at the state, regional or federal levels. For example, a regional planning agency at hazard mitigation is the consideration of drainage or evacuation issues within the Development of Regional Impact (DRI) review process. A federal effort is the National Flood Insurance Program. A state effort would be the drafting of rules for hazard mitigation promulgated in the Post-Disaster Redevelopment Rules, Chapter 9G-13, FAC.

Effective hazard management requires a mix of both preventive and corrective measures. In the case of coastal flooding, a recommended preventive measure would be to discourage the development of high risk areas through some form of land use regulation. Coastal high risk areas are synonymous with NFIP "V Zone" designations which are delineated based on the expected inundation that would be caused by the "100 year storm", a severe storm event which has a 1 in 100 probability of occurring each year.

The reduction of future flood loss reduction of storm-related damage and limitation of development pressure in coastal high hazard areas can be achieved through hazard mitigation efforts. Much of Florida is low-lying and therefore quite vulnerable to floods associated with hurricanes, presenting a problem which has the potential for exacting enormous repetitive costs associated with insurance payouts, disaster assistance, and the possible loss of human lives.

Florida's recent experience with hurricanes Kate and Elena brought about a state government review of policies dealing with the costs associated with hazard mitigation, disaster assistance, post disaster redevelopment, and selective post-disaster acquisition. Consider the following: damage assessments from hurricane Elena, even though the state did not receive a direct hit, shows that enormous damage was done to state roadways, bridges and public property including utility facilities.

Storm Surge - One of the most devastating elements of the hurricane is the high tide which floods the coastal area. A rise in the ocean water level is generally caused by a storm approaching the shoreline. The height of the surge during a hurricane is dependent on a number of factors, which include offshore water depth, wind speed and storm speed. Often, storm surge height is greater in a bay than along the open coastline, primarily due to a concentration of storm energy resulting in a "funneling" effect.

The maximum storm surge may be expected 10 to 50 miles to the right of the storm track or in the direction of the on-shore hurricane winds. Thus for Atlantic coastal storms the greatest surge levels are usually to the right of the center if the storm makes a landfall, and to the left of the center as it moves from land to sea facing in the direction of storm movement (See figure 9).

The onset of the storm surge is usually characterized by a gradual rise in the sea level when the hurricane may be as much as 500 miles offshore. As the storm moves toward the land, the level of the water continues to rise, reaching its maximum at about the same time the eye of the hurricane makes its landfall. High tides can occur all along the coastline during a severe hurricane and are not confined to the immediate storm center.

In a hurricane, the increased water level is a function of two major factors: barometic pressure and high wind velocity. The low barometric pressure found at the center of the hurricane may raise the water level one foot for each inch of pressure reduction. This if often referred to as the "inverted barometer effect". The high winds associated with hurricanes cause the water to shoal or pile up as the storm moves toward the coast, which increases its depth.

Waves - With the exception of seismic sea waves

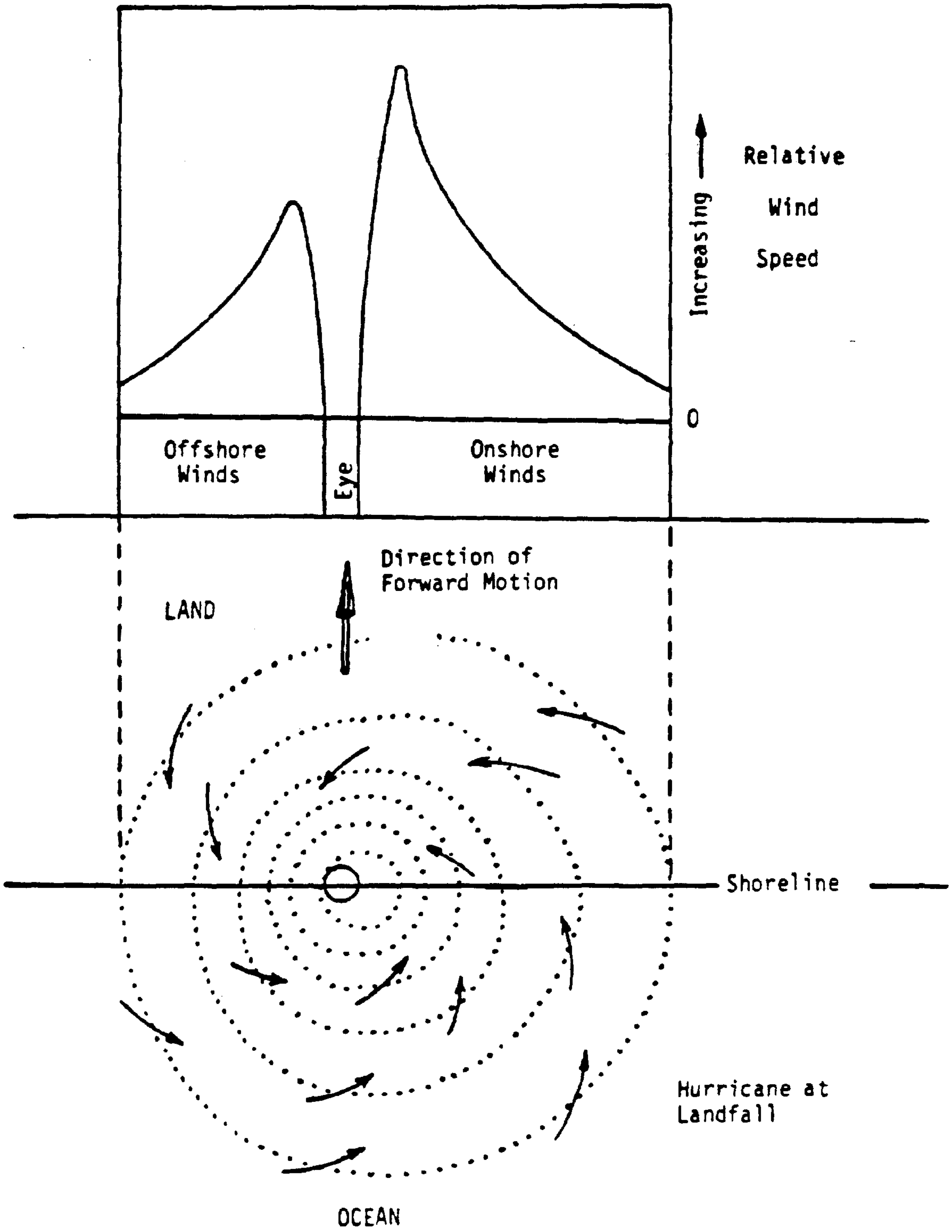


Figure 9

Conditions of a Hurricane at Landfall (Source: Balsillie, 1978).

(i.e., tsunamis), "wind-generated waves produce the most critical forces to which coastal structures are subjected. A structure exposed to wave action ideally should be designed to withstand the highest wave expected at the structure" (Coastal Engineering Research Center, 1975).

There are many factors which influence the height of the storm waves; these include the wave period, wave length, bathymetry and wind speed. These factors also have a significant effect on the two major components of the wave force: vertical and horizontal wave pressures. The horizontal impact pressure of the storm wave has a tremendous destructive potential when breaking directly on coastal structures, while the vertical component has the effect of producing uplift pressures on the structure as the waves peak (See figures 10 & 11). Balsillie (1980) indicates that wave peaking on structures can be of such magnitude that "uplift pressures associated with the peaking may be an integral factor leading to structural failures." Horizontal impact pressures, or "shock" pressure can be defined as high, short duration, dynamic pressure acting against a vertical, rigid structure (e.g. a wall) as the result of a uniform mass of water produced by breaking activity striking a rigid vertical surface (Balsillie, 1978). The greatest destructive hazard

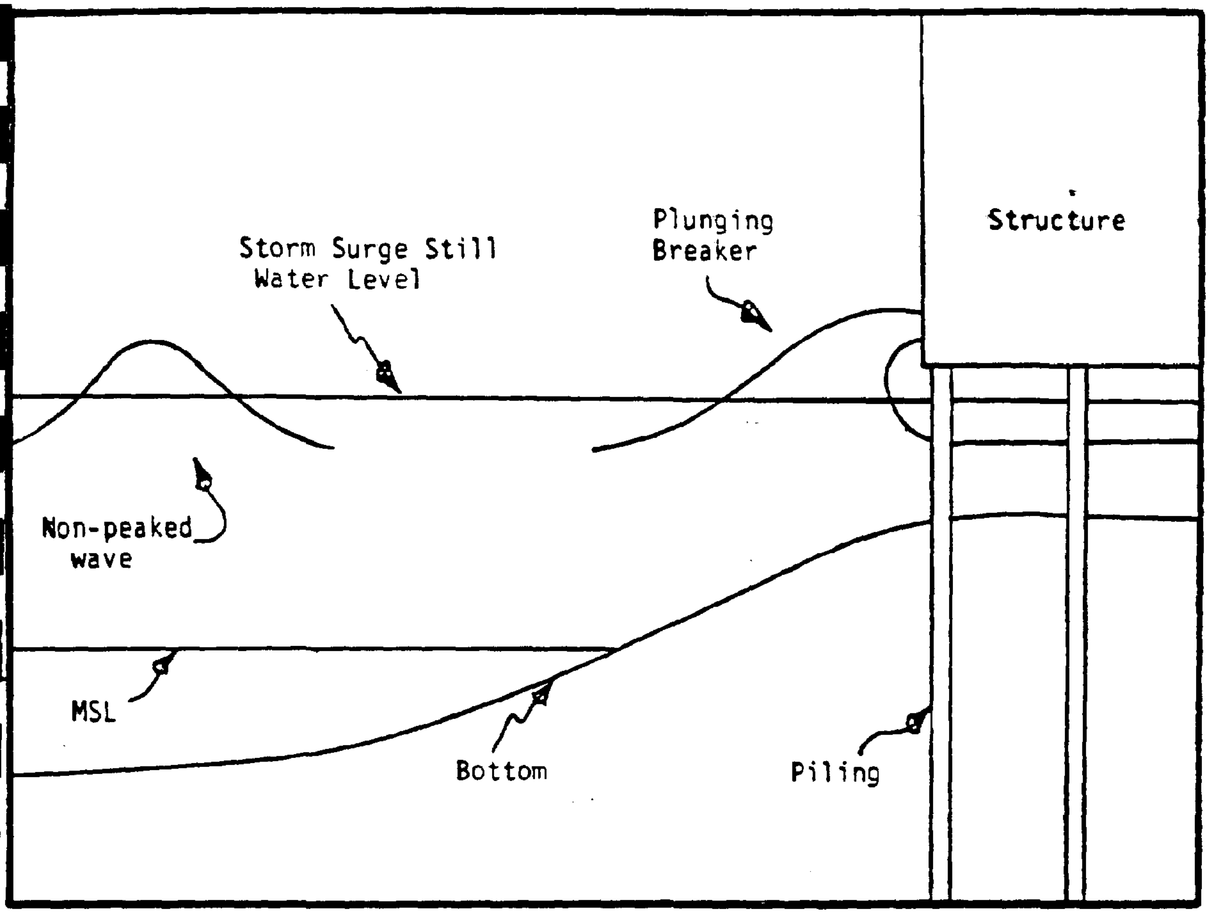


Figure 10

Direct Horizontal Wave Force
(Source: Balsillie, 1978B)

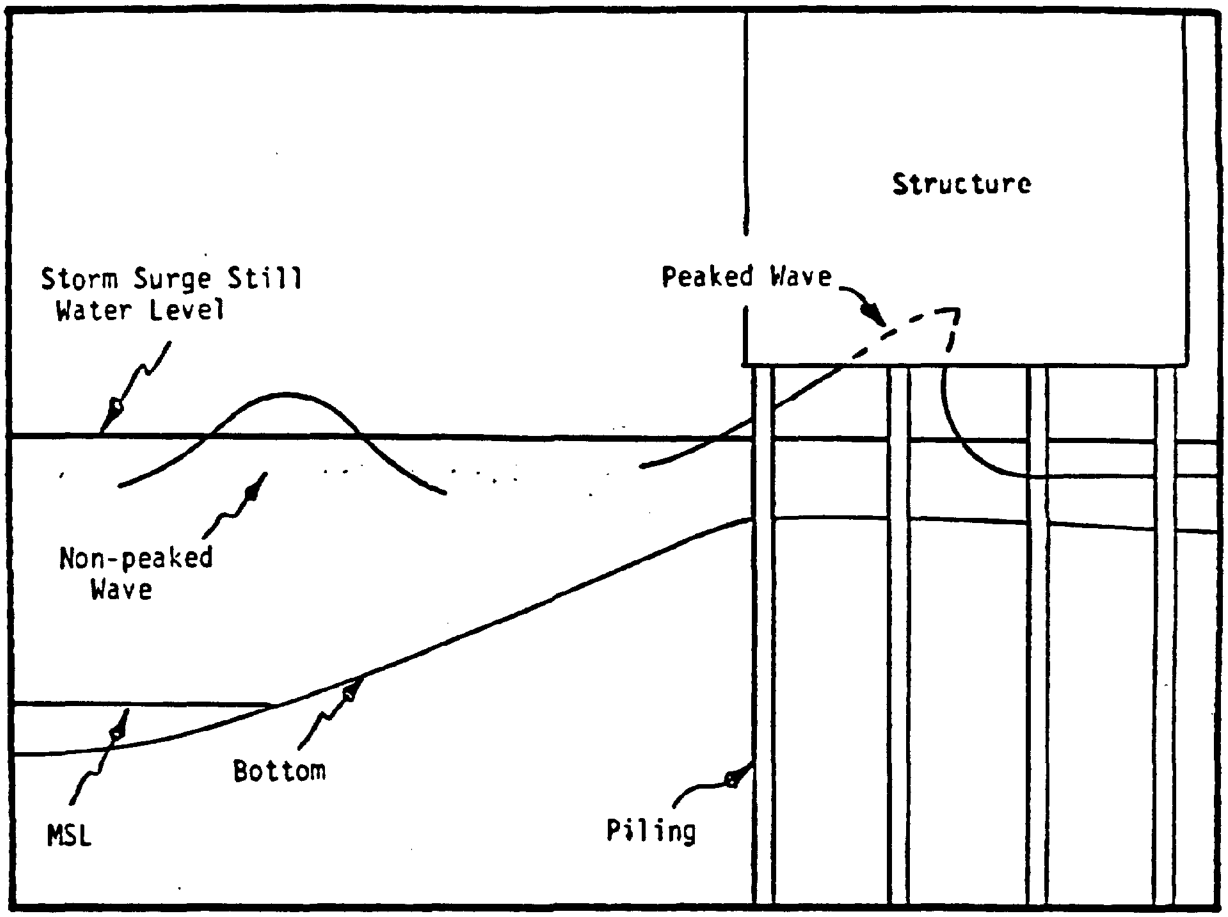


Figure 11
Direct Vertical Wave Forces Caused by Peaking Waves (Source: Balsillie, 1980).

potential from the horizontal component of the wave occurs after a wave has undergone shore-breaking, while the next largest hazard results from "plunging waves breaking directly on vertical walls", Balsillie, 1978).

Winds - The shore and nearshore regions are often characterized as windy areas, having little topographical relief to slow down wind gusts. The following excerpt from "Florida Hurricanes" (Dunn, et al., 1967), presents a descriptive look at hurricane generated winds in Florida:

> Wind - Wind records in a hurricane are often interrupted before the maximum speed is recorded. Because of the delicate design required of instruments for accurate readings at average speeds, anemometers have frequently failed or have been blown away when the speed reached the vicinity of 120 mph. With the spacing necessary between observatories and the fact that the strongest winds are confined to a relatively narrow band around the eye, it can be seen that it would be fortuitous to have the maximum winds of any hurricane occur at a first order weather station. Nevertheless, a few readings of over 150 mph have been obtained. From theoretical calculations, based on pressure gradients and structural damage, it is estimated that sustained winds in a few of the most severe hurricanes have exceeded 200 mph. It is possible for momentary gusts to be a much as 25 to 50 percent higher than the sustained winds. Therefore, in a storm with a sustained 100 mph wind, there could be gusts of 150 mph; and in one with 150 mph sustained winds, maximum gusts might be over 200 mph. Since the gustiness is responsible for the damaging intermittent pressures and wrenching effects, the speed of the peak gusts must be considered in designing structures to withstand hurricanes. The rapid rise in the actual force of the wind at higher speeds is another important factor in relation to construction and wind damage. The force exerted by the wind does not increase proportionally with the speed, but with the square of the speed, thus doubling the speed results in approximately four times the force. A wind of 60 mph

produces a pressure of about 15 pounds per square foot but a wind of 125 mph exerts a pressure of 78 pounds per square foot and results in a several-fold increase in destructive capacity over that of the 60 mph storm. Record Winds in Florida - The Keys hurricane of September 2, 1935, which caused the loss of over 400 lives and great damage, is the most violent hurricane on record in Florida's history. This was a small storm with the strip of principal damage only about 40 miles wide. No anemometer reading of the maximum wind was obtained, but engineers estimated, from the force necessary to accomplish the observed destruction, that sustained winds exceeded 200 mph. A good central pressure value was obtained and calculations of maximum wind based on the pressure-gradient formula gave similar results. A speed of 121 mph (one minute) with gusts to 155 at Hillsboro Lighthouse, a short distance to the right of the center, was registered in the Fort Lauderdale hurricane of September 17, 1947. At Miami, in the October 1950 hurricane, sustained winds reached 122 mph with gusts of 150 mph. This was a very small storm compared to the 1926 Miami hurricane in which the wind reached 123 mph before the anemometer failed. Stations farther north on the Florida east coast have not reported speeds as high as these, the maximum on record prior to 1964 being under 100 mph. This does not indicate that major hurricanes cannot occur anywhere in the state; it may merely reflect the fact that since more hurricanes affect the extreme southern portion, there are more opportunities there for obtaining records of high winds. No section of Florida should be considered immune to violent hurricanes.

Coastal Erosion - Shorelines are found to be in a state of erosion, accretion, or equilibrium, either naturally or artificially. Erosion produces a net loss in land along the coastline, accretion produces a net gain in land, and equilibrium conditions result in no net change. Shoreline changes are the response of the beach to a hierarchy of natural cyclic phenomena including tides, storms, sediment supply and relative sea-level changes. Shoreline erosion assumes importance along the

Florida coast because of active loss of land, as well as the potential damage or destruction of piers, energy facilities, highways, and other structures.

When a hurricane moves onshore, its high-velocity winds, attendant waves and currents of destructive force scour and transport large quantities of sand. The amount of damage suffered by the beach and adjoining areas depends on a number of factors including angle of storm approach, configuration of the shoreline, shape and slope of the ocean bottom, wind velocity, etc. Shorelines experience their greatest short-term changes during and after storms.

The extent of beach erosion is especially critical in areas having structures along the shore. The overall storm action will loosen and scour the sand underneath slab-on-grade foundations. This action has the effect of causing the structure to become unstable and thus subject to failure and collaspe.

Impacts of Hurricanes - At the shoreline proper, inundation by the storm surge, and the accompanying storm waves can be one of the most destructive elements of a hurricane. The tremendous force of a wave can be realized when considering that a cubuc yard of water weighs over three-fourths of a ton; hence a breaking wave moving shoreward at a speed of up to 60 miles per hour will have devastating effects on structures subject to storm surge mandation (DCA, 1980).

Wind forces exerted on structures during a hurricane can have the same devastating effects particularly in conjunction with wave forces. For example, a 100 mph wind at an elevation less that 30 feet above mean sea level (MSL) exerts a pressure or force of about 26 pounds per square foot on a flat surface. Furthermore, the pressure varies with the square of the velocity. Therefore, a wind of 140 mph velocity at an elevation less than 30 feet above (MSL) would exert a force of 152 pounds per square foot. Also, wind increases with height above ground, so a tall structure is subject to greater pressure than a low structure (Pilkey et al., 1978).

Generally, wave and wind forces on structures during a hurricane will have similar impacting consequences, unless structural design techniques are implemented to mitigate these forces. For example, direct horizontal wave (See figure 10) and wind forces will cause inadequately designed structures to laterally move off their foundations, laterally collaspe from racking, or lose parts of the structure by material failure or connection separation, all of which can cause structural collaspe. (See figures 12, 13, 14 and 15).

Direct vertical wave forces caused by peaking waves (See figure 11) will cause structures not securely anchored to overturn (See figure 16) or be laterally moved off their foundations. Structures that are anchored securely but are not elevated high enough above the peaking wave level may experience floor cracking leading to flooding and possible floor collaspe.

In addition, wave and wind can also cause severe battering damage not only in forcing water onshore to flood buildings, but also in throwing floating and wind blown debris against standing structures (See figures 17 and 18).

Many of the indirect forces of velocity flooding, such as the erosional processes of scouring and horizontal recession can destroy coastal structures by undermining the soil that underline foundations, thereby causing the structures to collaspe (See figure 19).

In summary, the battering process of rushing water, waves, and objects floating in the water, in conjunction with high velocity winds can create extensive damage to facilities and structures in the coastal high hazard area. However, with coastal construction code requirements which take into account frequency levels of storm surge and wind velocities, many of the direct and indirect forces caused by coastal storms can be mitigated.

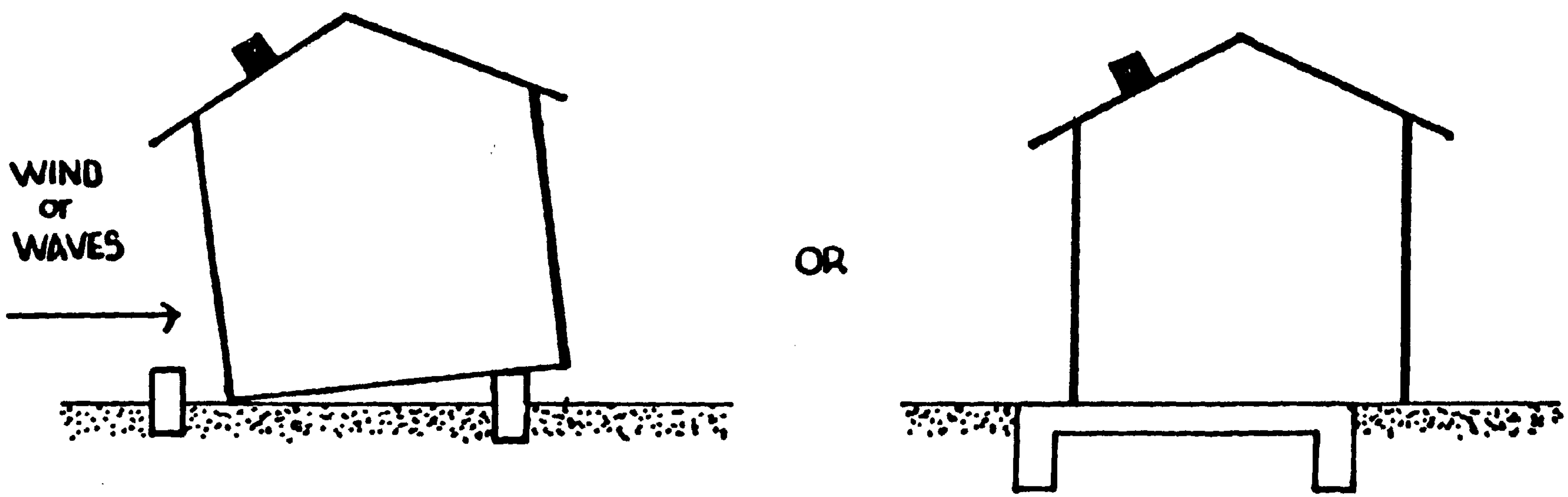


Figure 12

Lateral Displacement: Direct Horizontal Wave and Wind Forces (Source: Pilkey, et. al, 1978).

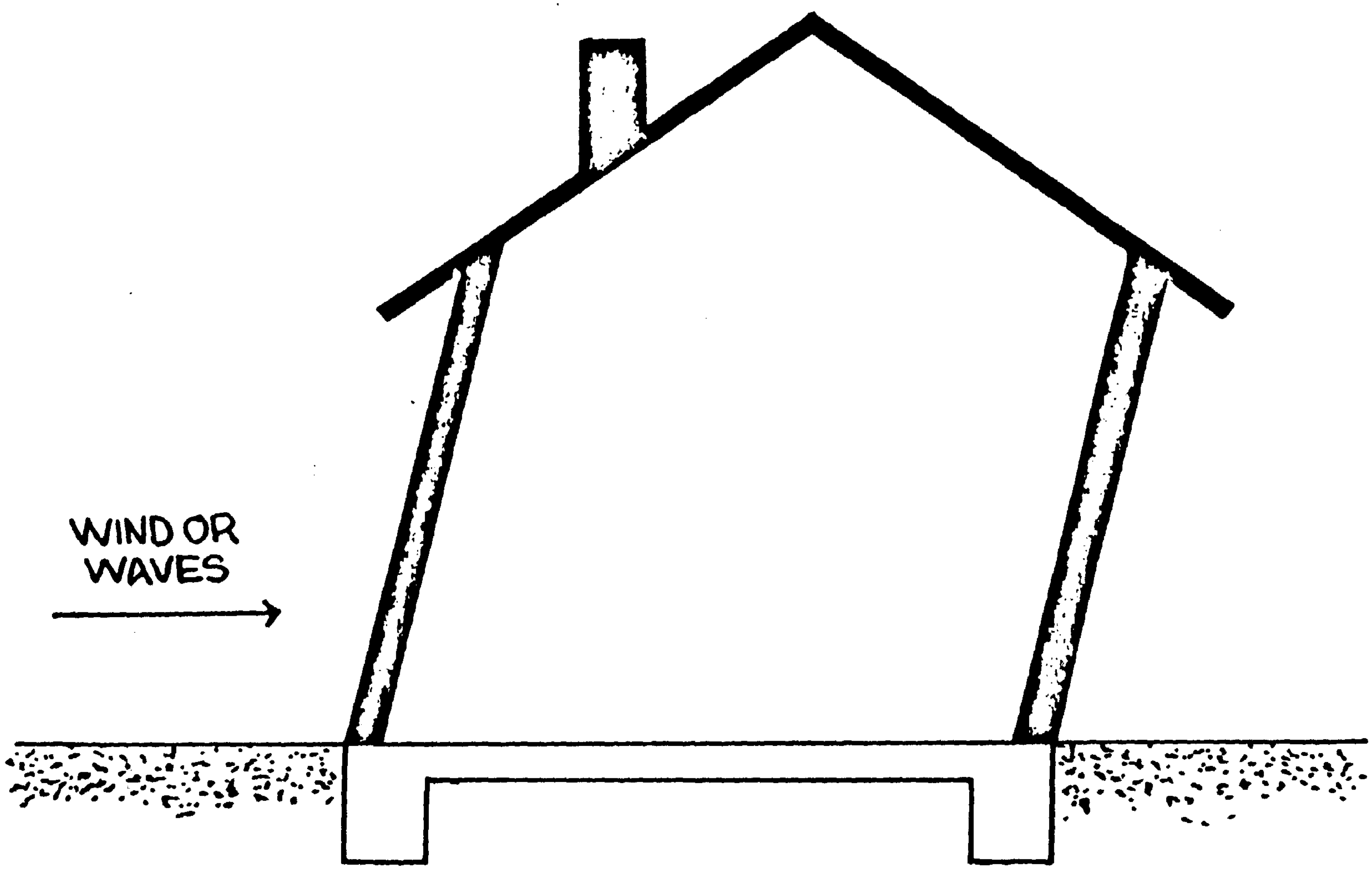


Figure 13
Lateral Collapse From Racking: Direct Horizontal Wave and Wind Forces (Source: Pilkey, et. al, 1978).

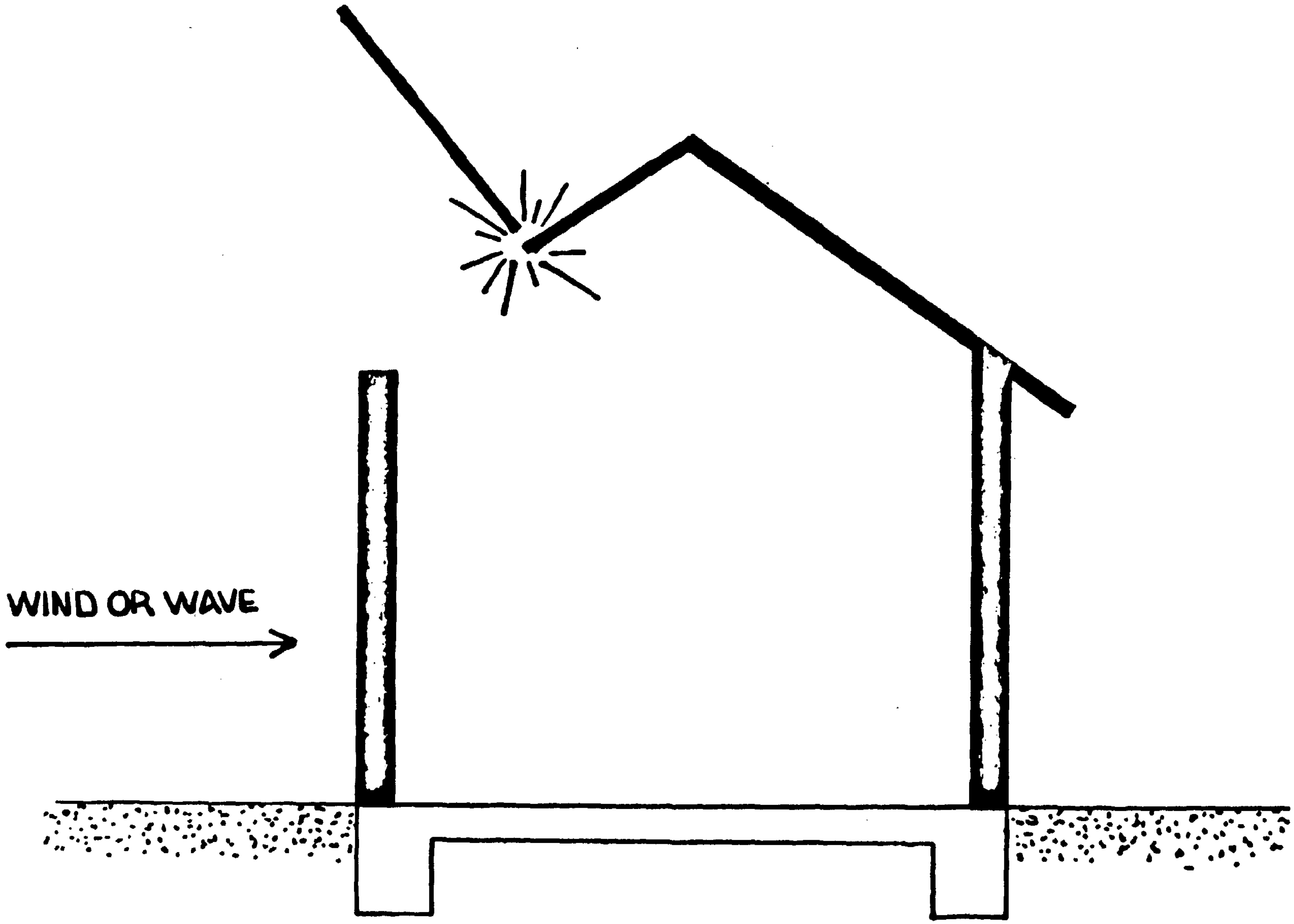


Figure 14

Structural Damage Due To Material Failure
Or Connection Separation
([redacted] Pi[redacted]y, [redacted] a[redacted]97[redacted]

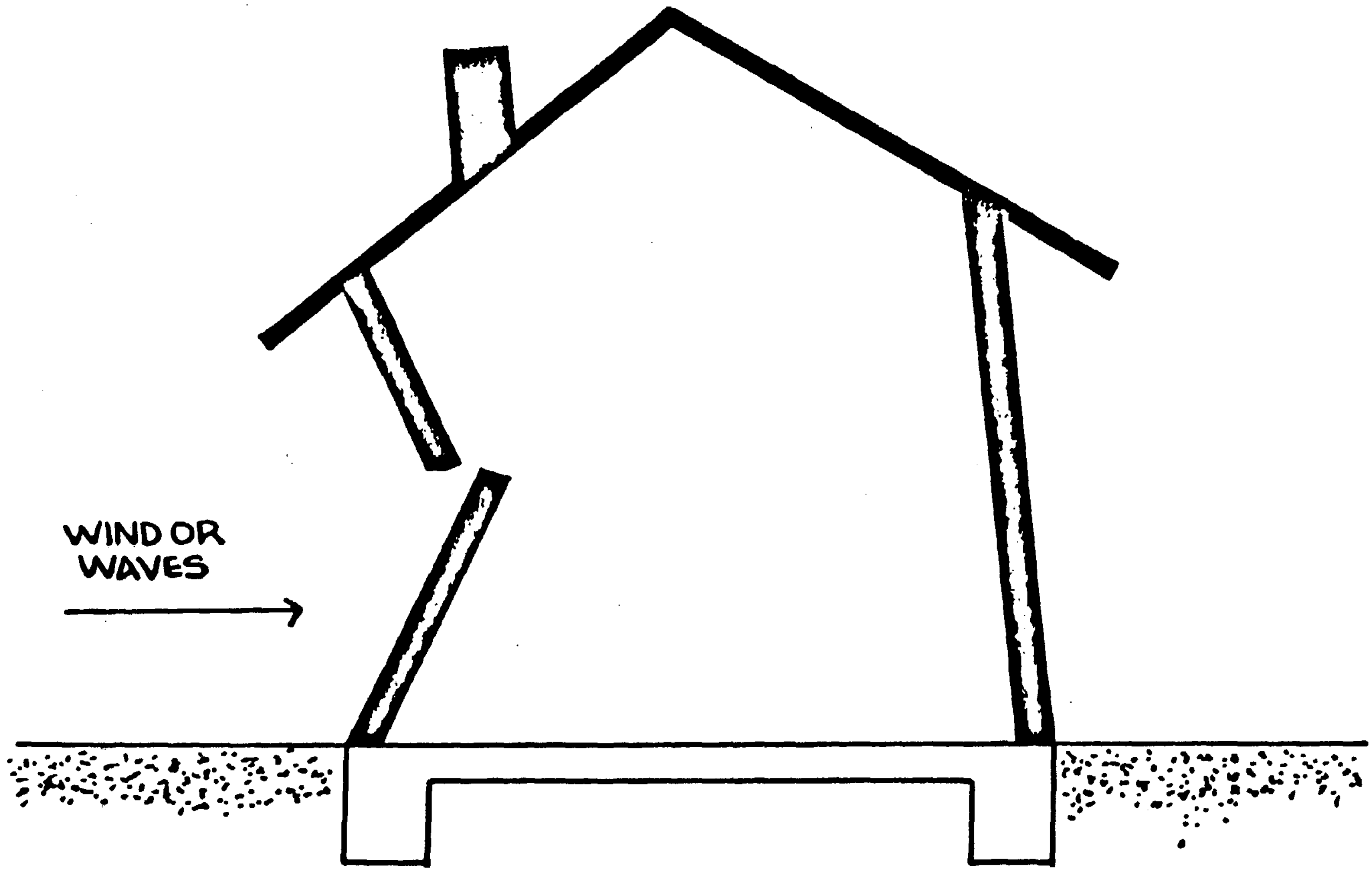


Figure 15

Structural Collapse: Direct Horizontal Wave and/or Wind Forces (Source: Pilkey, et. al, 1978).

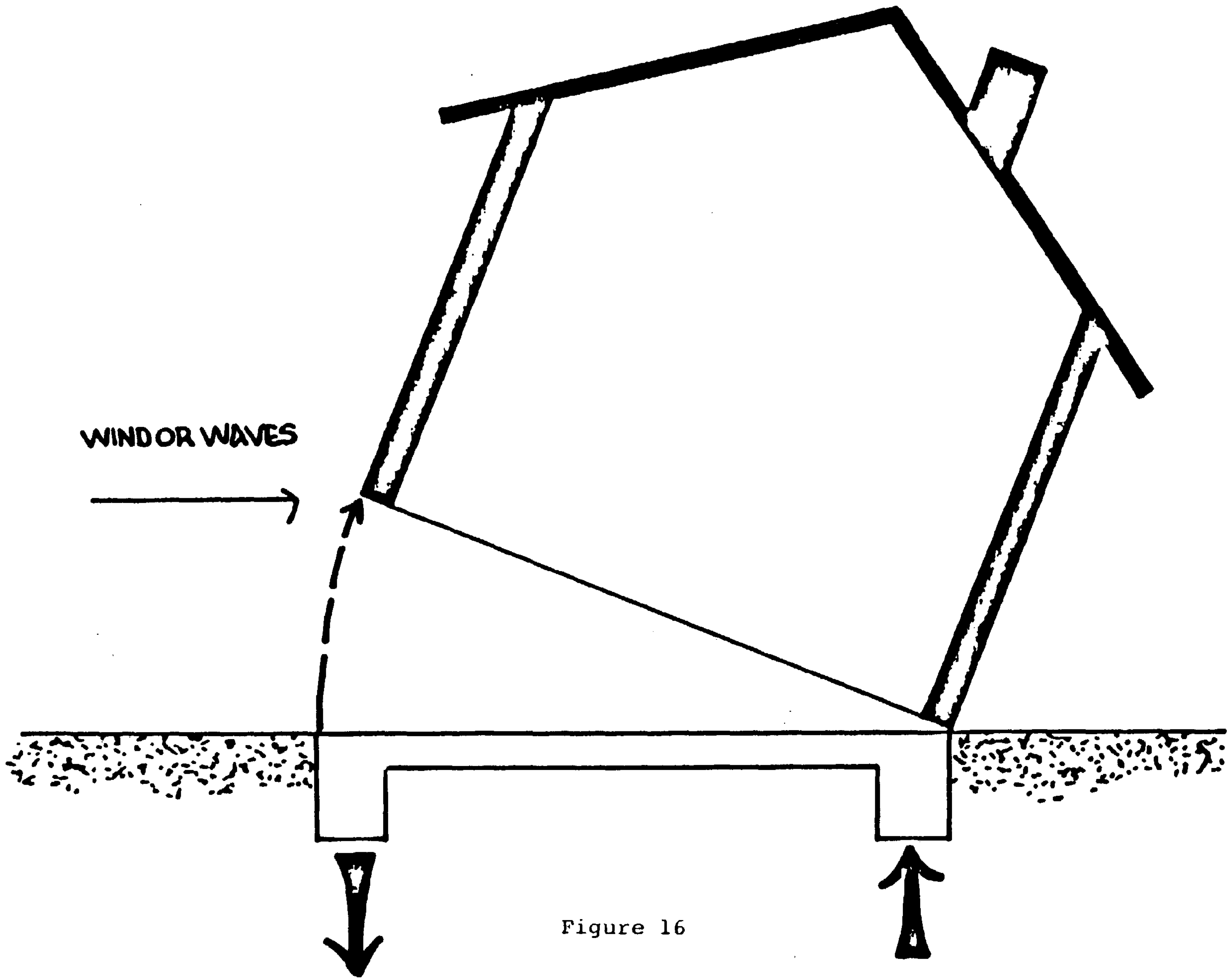


Figure 16

Overturning: Direct Vertical Wave Forces
(Source: Pilkev, et. al, 1978).

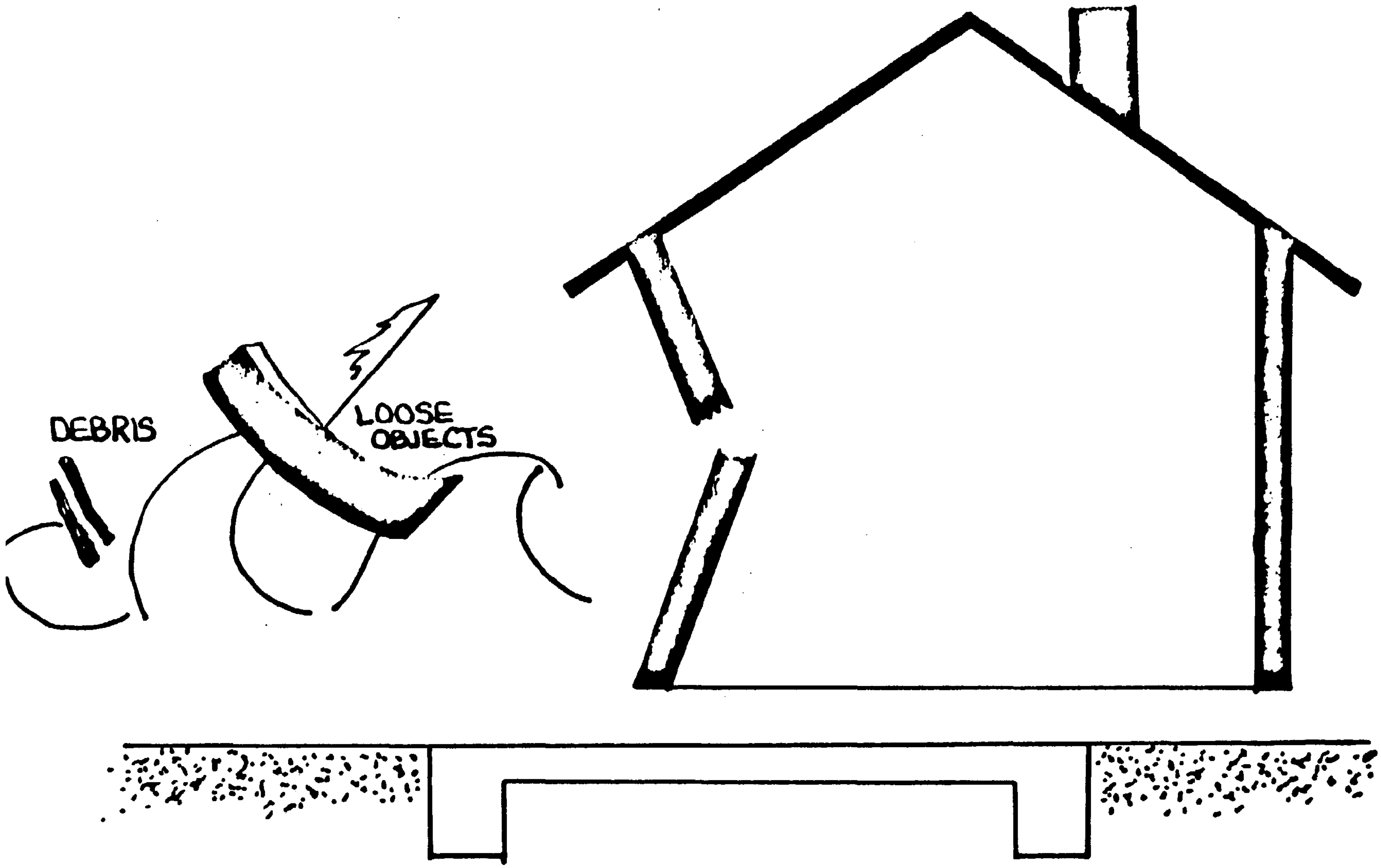


Figure 17

Debris Battering by Wave Driven Objects (Source: Pilkey, et. al, 1978).

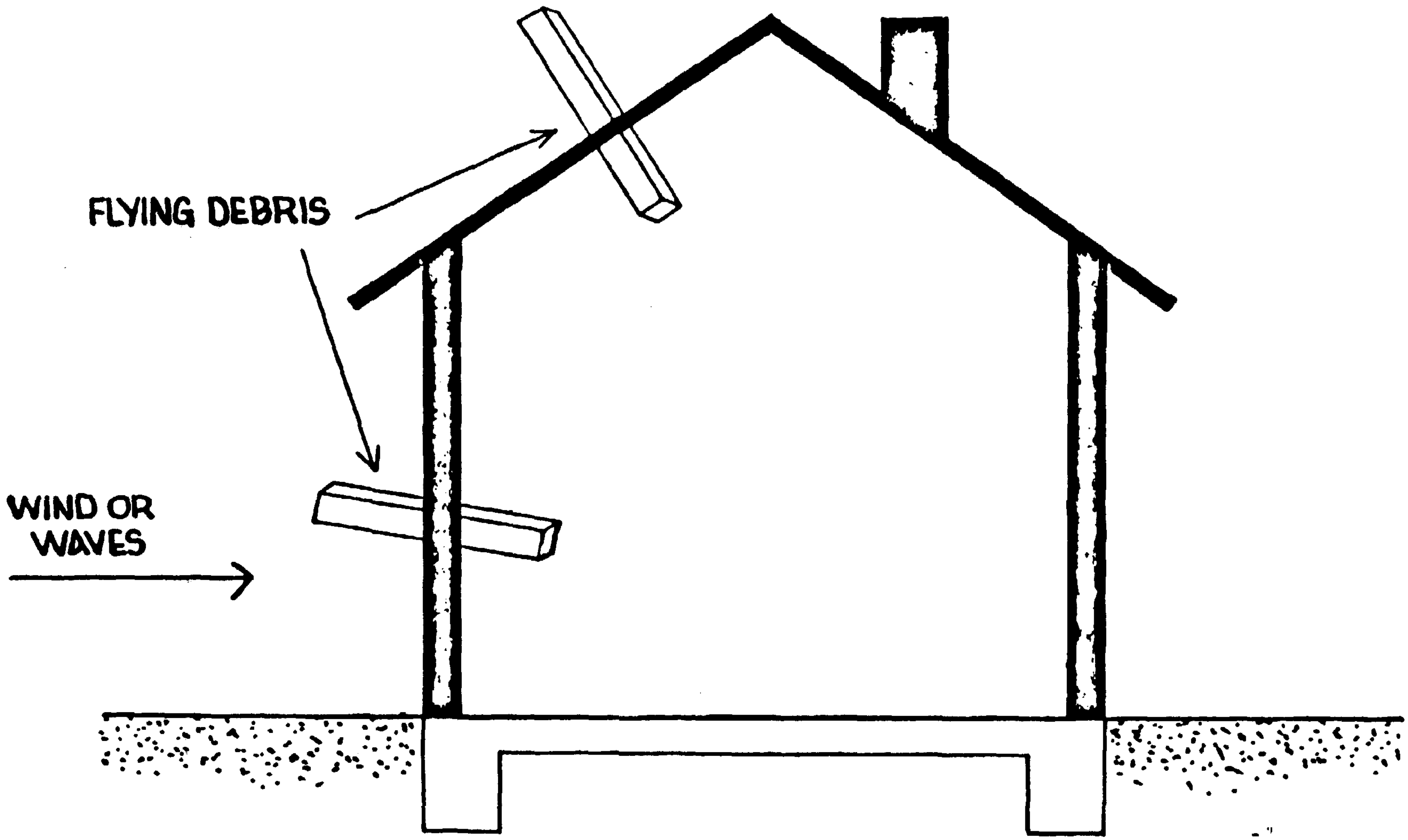


Figure 18
Debris Battering by Wind Driven Objects
(Source: Pilkey, et. al, 1978).

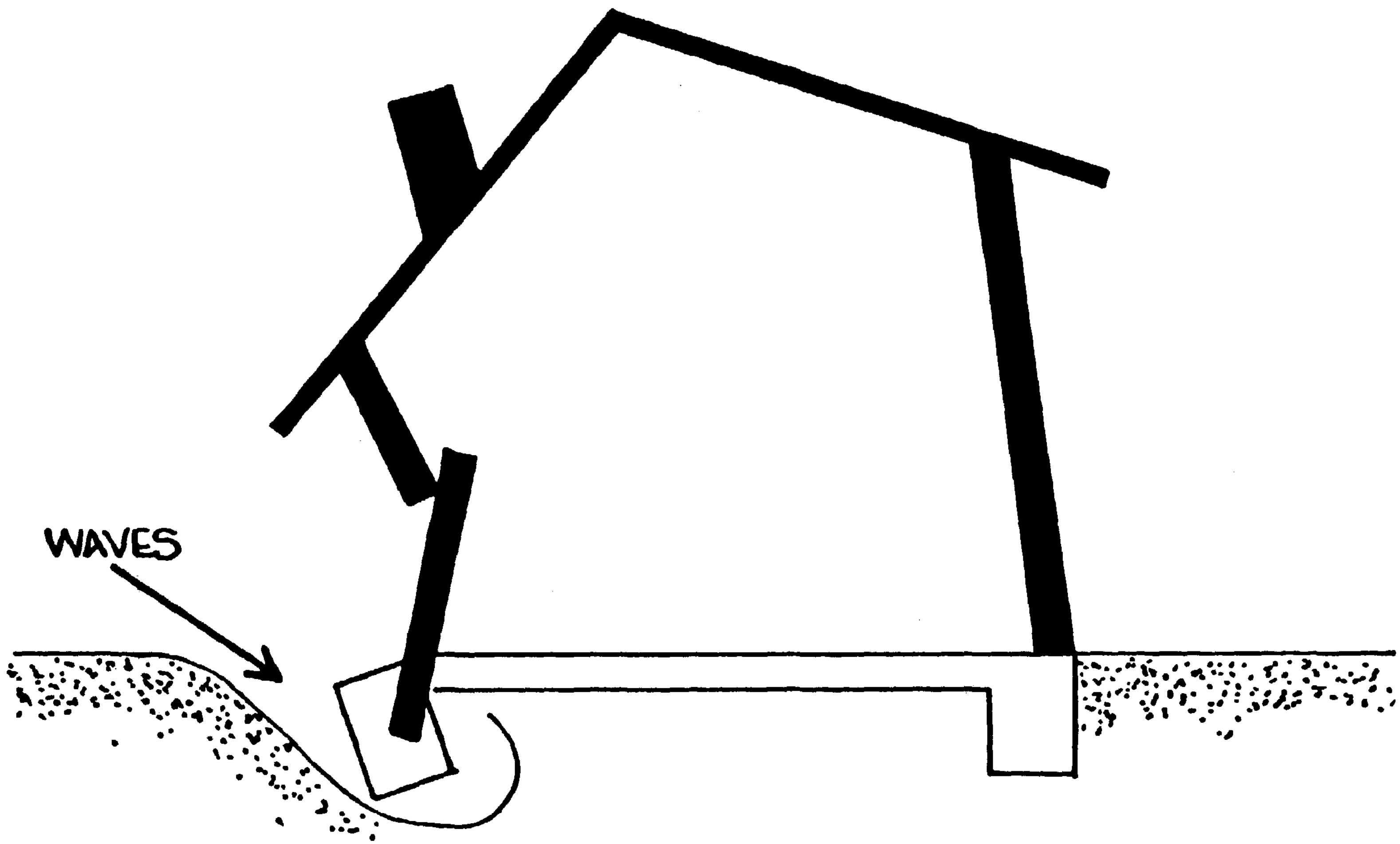


Figure 19

Structural Collapse Caused by Scouring and Horizontal Recession (Source: Pilkey, et, al, 1978).

IV. Siting Options in the Coastal Zone

Because of Florida's burgeoning growth it is reasonable to expect that the demand for increased sources of energy will continue in the State. This will require expansion of energy facilities with most if not all, being located at or near the coastal regions of the state. By location of facilities at coastal sites the probability of being affected by a storm or hurricane event is increased. Damage from a major storm event can be mitigated through site selection and technologies that mitigate as many adverse impacts as possible. The regulation process by the state should (1) involve a thorough review of all available options and sites so that related problems can be understood, and studied and (2) culminate in a decision that clearly reflects the best long-term interest and needs of the region and state.

While the state is concerned with minimizing hurricane damage to life and property local units of government have the most direct control over public property including public buildings, roads, and utilities. Therefore, local governments can choose design standards, materials, operating procedures, and locations for public facilities and other public property toward this objective.

Construction techniques , which apply to buildings as discussed earlier in building codes, varies from jurisdiction to jurisdiction. However local governments may exceed minimum requirements of the building code and comprehensive plan for its own buildings (e.g., by not locating in V Zones and by using higher minimum elevations). There are six basic general techniques for reducing or avoiding hurricane related damages:

- Elevation
- Anchorage
- Design for Extreme Conditions
- Siting
- Temporary relocation or modifications
- Changes in operating procedures

Examples of more specific techniques within these categories are shown in Table 6. A brief discussion of each general technique follows.

Elevation - Placing the most expensive and water-damage prone parts of structures and their contents above the expected heights of the storm surge and waves is an obvious measure which can be expected to reduce or eleminate damages from water entry. Utility connections can also be arranged so that they are above flood elevation as much as possible. This is a straightforward approach for above-ground electrical connections, telephone lines, water meters and so forth, but not practical for risers which connect underground utilities to elevated structures. A caution is necessary that elevating structures can expose them to additional or more severe forces than for non-elevated structures.

Placing underground utilities below expected scour depths in another elevation-based techniques which requires consideration of the groundwater environment which below grade construction will encouter. Obviously manholes and value control boxes will need a connection to grade level for access but they still can be supported below scour depth.

Anchorage - The importance of anchoring structures firmly to stable soil cannot be over emphasized. There are two purposes of anchorage: (1) maintaining the intergrity of the structure (e.g., avoiding having an otherwise intact elevated structure lift off its foundation and 2) keeping structures or large mobile objects in place so that they don't become projectiles or battering rams (e.g., unmoored boats). Typically minor structures such as sheds accessory to main buildings are exempt from building code stormproofing requirements. Consideration should nevertheless be given to ways in which to keep these minor structures in place even when they aren't intact.

Design for Extreme Conditions - To protect energy facilities from the affects of flooding from a storm event, berms or levees may be considered for certain facilities, energy dissipators can include seawalls and riprapped shoreline areas which should be designed considering their effect on erosion.

Siting - Siting considerations have been discussed previously in this report. A key point to be made is that energy facilities can be sited with discretion by local governments. Local governments can choose to locate structures, especially energy facilities, more selectively under provisions of comprehensive plans.

Temporary Relocation/ Modification - While temporary relocation of an energy facility is impractical during a storm event, modification of the structure to mitigate hazards and reduce damage potential can be accomplished through floodproofing techniques. Temporary measures which can reduce damage include protection of exposed glass with wood or other suitable panels less susceptible to breakage. This can be done with removable wall or deck panels which then become less susceptible to damage as well as reducing wind or water loads on the structure by their absence.

Changes in Operating Procedures - Emergency procedures to prevent damages are based partly on removing hazards. Closing valves reduces fire, explosion, and contamination risks and consequently non-flood damages caused by damage to energy facilities.

TABEL 6

Techniques to Reduce Hurricane Damage to Property

1. Elevation

   * of structures or parts of structures above flood levels
   * of utility connections above flood levels
   * of underground utilities below anticipated scour depths

2. Anchorage

   * tiedowns for minor structures
   * tiedowns for mobile structures and objects
   * substantial foundation to roof anchors for Major structures
   * tiedowns for underground structures including tanks and pipes

3. Design for Extreme Conditions

   * construction of berms or levees
   * additional reinforcing including wall shoring and pilasters
   * hydrostatic pressure equalization of blowout plugs, etc.
   * energy dissipators
   * cutoffs to prevent scour under roads
   * waterproofing
   * floodproof conduits and utility cores
   * watertight manholes
   * construct road sections as "land bridges"
   * slope ducts to drain
   * pressure sewers

4. Siting

   * outside of V Zone and areas subject to severe scour from ebb flow of storm surge
   * avoid shoreline areas with high erosion rates
   * take advantage of protective vegetation and stable dunes
   * away from existing inlets and finger canals
   * avoid historic overwash areas
   * site in wider parts of the island preferably by salt marshes

5. Temporay Relocation of Modifications

* remove and store removable/breakaway wall panels
* use removable decks to cover windows and glass doors
* close working shutters or use plywood covers
* insert waterproof door panels
* move contents above flood level
* allow water into structures not designed to withstand hydrostatic forces
* move public vehicles not in use to a floodproofed parking structure

6. Changes in Operating Procedures

* shut off non-emergency electrical systems
* switch to emergency generators
* close valves or sewers, gas, and water systems
* remove vegetation prone to windthrow

If balanced pursuit of Coastal Zone protection, urban development, and energy facility siting is to be accomplished, government should take the initative in need determination, site planning, and site selection. In some cases, clearly defined siting criteria can give government an appropriate anticipatory role, yet one short of assuming complete responsibility for designating specific sites. In other cases, actual site designation may be necessary.

In order to minimize the effects of storm-related damage to energy facilities, only water-dependent facilities should be located at the water's edge. All others should be located at a reasonable distance inland, removed from the immediate coastal land-water interface. Coastal Construction setback policies in the coastal zone and other regulations should enforce such a preference for inland siting.

This policy is designed to protect valuable ecosystem, in the coastal zone in addition to reducing the risks associated with hurricane and other storm events in the coastal zone. Too often in the past energy facilities have been located on rural or urban water fronts because of historical tradition. Now, however, avialable technologies --deepwater ports for unloading at an offshore location, pipelines for transfer of crude oil, natural gas, petroleum products, or other liquids from a coastal transfer station to an inland site for processing and storage--offer opportunities for environmental hazards mitigation and socially preferable inland, remote siting of needed energy facilities without an undue economic penalty to the energy company. Economic analysis indicated that the cost differential between locating a new oil refinery at an inland rather than coastal site would be relatively small (Morrell et. al. 1978).

In considering the suitability of locales for siting energy facilities and their susceptibility to storm related damage, it is essential to consider the facitity type and its use. A gas-processing plant is not a tank farm and an offshore oil and gas support base is not a power plant. Vulnerability to storm risks depends on the type of facility.

V. Summary and Recommendations

This report has provided an analysis of energy facilities by location which would be susceptible to damage in the event of a hurricane or other extreme storm event. In order to predict risks to energy facilities associated with coastal location it is necessary to identify coastal hazard areas that have different levels and intensity of hazard exposure.

The general delineation of these hazard areas can be identified based on an analysis of the processes and faces associated with a hurricane, examination of empirical damage data, and a knowledge of the meteorological, topographical or hydrological characteristics of the coast. In order for siting decisions to be made with regard to risk reduction, hazard areas must be explicitly identified and mapped. Although the National Flood Insurance Program is one of the few programs to attempt to do this through its flood mapping program, their methodology does not address the delineation of coastal high hazard areas with the exception of V Zone designations.

In addition to V Zone delineations there should be site specific surveys to delineate hazardous areas which may be subjected to hurricane force winds with associated storm surge and wave penetration, there are efforts underway in the state of Florida to generate quantitative information on the hurricane forces that impact coastal structures which, hopefully, will lead to design standards necessary for location and construction of energy facilities in the coastal zone.

In order to mitigate or reduce damage to energy facilities, management in relation to the hazard potential must be made. The following summary recommendations are in support of this ideal:

- Coastal Zone regulations in Florida should encourage inland, as opposed to coastal, siting and permitting of new energy facilities.
- Siting policy should distinguish among facility types and coastal characteristics so that specific hazards can be identified
- Innovative siting (for example, inland siting with a pipeline to the coast) should be encouraged.
- Energy facilities should be required to present storm hazard mitigation plans during the siting process.
- Where safety issued are the dominant concern (e.g. Nuclear Power Plants, liquified natural gas) remote siting with defined buffer zones should be required.

In conclusion, hazard mitigation policies for energy facilities are part of comprehensive emergency management system for dealing with hazards associated with hurricanes. In order to be effective they must be used in conjunction with other management tools such as building codes and coastal construction requirements.

There are a number of hazard mitigation techniques available for reducing damage to energy facilities during a storm event. Unfortunately no facilities can be designed or built to withstand all possible forces of nature without some damage. It is important to recognize that mitigation measures are extremely important in efforts to minimize or lessen the damage due to hurricanes or other severe climatological events.

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